HANDBOOK OF AGING AND THE INDIVIDUAL

PSYCHOLOGICAL AND BIOLOGICAL ASPECTS

EDITED BY

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Preface

This book is the product of the efforts of many people, and its publication is the final manifestation of about 10 years of thinking and discussion about the need for a handbook of this sort The major concern of the book is with the biological and psychological bases of aging the bases of changes in behavior and capacities of the individual organism which occur with advancing age

Specifically the purpose was to prepare a handbook which would be an authoritative technical summary of the scientific and professional literature on the individual or behavioral aspects of human aging with supporting information from infrahuman species The preparation of such a summary was regarded as necessary in organizing and developing the subject matter for undergraduate and graduate education and research It is primarily intended for use by graduate students and professional and scientific specialists as a reference work

The chapters reflect the intent to organize a definitive secondary source of data in a field which has a widely scattered literature Chapters are comprehensive but do not necessarily review or refer to all the literature on a specific point As compared with an annual review of a subject the chapters attempt to present a more systematic organization of information Not only was the handbook to organize what is known in a convenient form it was also to serve research and pedagogical purposes by pointing out crucial or systematic theoretical problems No special emphasis has been placed on practical matters and authors were encouraged to concentrate on the creative task of organizing the previous scattered ideas and data The view was held that the present work would lead toward the scientific or rational bases upon which service to the aging and aged will ultimately be advanced

The remote parentage of this volume is difficult to trace but it is an outcome of activities of the Gerontological Society and of the Division on Maturity and Old Age of the American Psychological Association Formal planning for this volume began in 1956 as an activity of a research subcommittee of the Gerontological Society under the chairmanship of Dr Robert Kleemeier In July 1956 a meeting was held in Palm Beach Florida with the support of a grant (3M 9114) from the Training Branch of the National Institute of Mental Health to the University of Florida The committee invited several guests to partake in the discussions of what might be done to develop training opportunities in specialties related to mental health and aging Members of the committee were John E Anderson Ernest W Burgess James E Birren Ewald W Busse Wilma Donahue Clark Tibbitts and Robert W Kleemeier Guests were Robben W Fleming Raymond G Kuhlen Maurice E Linden Sidney Spector Gordon F Streib Samuel H Thompson Otto von Mering and Irving L Weber The report of this meeting contained among its recommendations that a handbook of psychosocial gerontology be organized This recommendation eventually was broadened in concept and then modified to divide the material between two volumes with separate emphases on the individual and on society Dr Wilma Donahue was named by the meeting to take the responsibility of carrying forward the recommendations

Participants in the 1956 Palm Beacl Conference helped to define the objective: and method of developing the present volume which were incorporated into th

final (1957) proposal The proposal was supported by grants from the National Institute of Mental Health (3M 9118) and the National Heart Institute (HTS 5205) to the University of Michigan, which acted as the administrative center for a "Multiuniversity Sponsored Training Program for University Personnel in the Field of Social Gerontology" Represented on the interuniversity council were University of Florida, John S Allen, University of Minnesota, John E Anderson, University of Pittsburgh, Harry W Braun, Pennsylvania State University, Joseph H Britton, Washington University, Marion E Bunch, University of Michigan Fedele F Fauri, U[illegible] leming, U[illegible] Fried m[illegible], University of Chicago, Robert J Havighurst, Purdue University, Herbert C Hunsaker, University of California, Harold E Jones, University of Connecticut, Donald P Kent, Syracuse University, Raymond G Kuhlen State University of Iowa Woodrow W Morris, Duke University, Lloyd Saville, and Cornell University, Gordon F Streib The project executive committee was under the direction of Dr Wilma Donahue and consisted of John E Anderson, James E Birren Ernest W Burgess Ewald W Busse, Woodrow W Morris, Bernice L Neugarten, Clark Tibbitts, Irving L Webber, and Richard C Wilcock

The editorial functions and the preparation of chapters by staff members of the National Institute of Mental Health were supported by the intramural research program, project M P A 11, as an activity of of the Section on Aging of the Laboratory of Psychology

An editorial committee was appointed for this volume, consisting of Drs John E Anderson, Ewald W Busse, and Albert I Lansing, which helped formulate editorial policies Ultimately, the final common pathway between the authors and the press was through the editor, who tried to reflect in the many, many decisions in a book of this scope the climate of opinion about the volume which had been built up It has taken almost four years for this book to emerge from the original proposal This may seem long to the contributors, yet to the editor it seems incredibly fast It has been a pleasure to work with authors who are deeply interested in their subjects and who strove so energetically to bring organization into the field, to them I express my gratitude

J E B

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PART ONE

Foundations of Research on Aging

I

Principles of Research on Aging

JAMES E BIRREN

I Introduction

The large differentiations of structure and function which occur with advancing age are a matter of considerable scientific interest and serve as a point of departure for an increasing amount of research in the sciences concerned with living things If one waits long enough, it is very likely that every individual will show characteristic changes of aging Thus the implications of research on aging are so vast, like those of evolution and natural selection, that the consequences of facts and theories appear both in the biological and social sciences and in the literature of an informed public.

Research on aging is a late arrival in science, trailing the fields of growth and development by several decades Publication of the first major compendium was in 1939 with the appearance of Cowdry's *Problems of Ageing*, although a few early biologists had reported research on aging Minot in 1908, Child in 1915, and Robertson in 1923 The early literature on the biology of aging has already been reviewed by Lansing (1952), by Comfort (1956), and by Medawar (1957) Although G S Hall published a book on *Senescence, the Last Half of Life* in 1922, research on the psychological aspects of aging did not begin seriously until the work of Walter Miles and associates about 1930 The research conference of 1955 summarized the available psychological literature (Anderson 1956) The Social Science Research Council established a Committee on Social Adjustment in Old Age in 1943 and in 1948 published a "Research Planning Report" on the subject (Pollack, 1948) While persons over 65 have a relatively high proportion of dependency problems resulting from a variety of health, psychological, and economic factors (Sheldon, 1948), it was not until the proportion of older persons in the population rose appreciably that professional services were given concerted attention Interest in the organization of professional services for aged persons began to grow after World War II (U S Federal Security Agency, 1951, Hobson, 1957, Tunbridge, 1958)

The recency of aging as a subject matter within science prevents us from having a satisfying perspective about it, however, its recency is in itself of interest. From a detached view there is no reason why research on any particular phase of the life-span should yield more knowledge than any other Social-cultural values have undoubtedly played a role in earlier emphasis upon research on childhood and processes of growth Youth has been the traditionally preferred period of life to study, whereas research on aging may provoke uneasy feelings rationalized by regarding it as an unsuitable subject for objective examination Uneasiness about the objective study of aging has likely produced a drag effect on research effort, but indications are that research on aging has clearly gone through this stage The precise relations between

processes of growth and those of aging are just beginning to be explored Although starting more recently research on aging has benefited by the methods and experience gained from research on growth and development some of the investigators have transferred their research interests from the early to the later part of the life span Various sciences have contributed to the study of development just as they are in aging and no attempt has been made in this *Handbook* to look at the subject matter from the viewpoint of any particular science or profession

In the recent past the abundance of conjecture philosophical bias and the absence of data would have supported a pessimistic view about the likelihood of having an orderly collection of facts and ideas about aging Yet the chapters of this *Handbook* show that it is not only possible but that we are well on the way to possessing a systematic body of knowledge Research on aging is controlled inquiry into the many differences between young and old organisms The research may be manipulative or non manipulative in its controls and may vary in the extent to which it is methodologically designed planned and evaluated in advance and the various decisions made susceptible to evaluation While there may be advocates of minimum design in research on aging collectively, investigators are interested in better ways of inquiring and improved methods Research on aging may be done well or poorly, with degrees of efficiency in between It can be seen in this volume that progress has been made and that the student of aging today is in a better position because he has (1) more facts available, (2) has more reliable and more different ways of securing data and (3) has the beginnings of theory to help organize his information and through familiarity and training he attains more precision in his statements about problems Research on aging is undergoing a metamorphosis into an experimental field and as the facts about aging increase more and more attention will be given to method and theory not only to manage and systematize the increasing data but also to save time in devising more efficient experiments As key problems become identified and as scientific interest in aging and the implications for man's well being converge in support of research, more investigators will be planning systematic studies Planning cannot be wholly anticipatory, since there is always the considerable chance of the importantly unexpected, the new method which "cracks" an old problem Keen observers will often sense a relationship in an accidentally produced situation The essential ingredient is an investigator who is aware of the problems of the field and is alert for new or different methods for their solution While admitting that we cannot predict what we will "discover" or predict the development of new methods which will accelerate problem solving we can, at any particular time in our knowledge, make choices between *more* or *less* efficient methods The best' methods of research cannot be prescribed but it is hoped that this *Handbook* will alert the reader and increase the probabilities of new insights and opportunities for borrowing techniques

The present volume has a special focus on behavior and the nervous system It is true that lower organisms without specialized nervous systems age and die, but for the more differentiated organisms like mammals the long lived neuron may epitomize aging and show more obviously the characteristics of aging it shares with all cells The nervous system is certainly in a key position to influence aging of the whole organism whether the influences arise in experience or from endogenous aging mechanisms

More specifically, the purpose of this chapter is to outline some of the issues of concept, explanation and methods common to research on aging This chapter also serves as an introduction to those which follow and which consider in detail most of the existing literature on specific aspects of aging Since the major emphasis in this book is on aging of the individual human,

with supporting data from pertinent studies of infrahuman organisms, primary concern in this chapter is with research about aging humans and their behavior

In this introductory chapter five principal topics have been selected and developed (1) the nature of explanation in research on aging, (2) the nature of research on aging, (3) research design, (4) aging and the organization of behavior, and (5) evaluation of research

II The Nature of Explanation in Research on Aging

It is the purpose of this section to examine some of the problems in explanation as they relate to research on aging If one is able to define a problem succinctly, he is usually well on the way to its solution Similarly, if one is able to communicate to others what problem or what aspects of the problem he is talking about, there is considerably less opportunity for confusion to arise about the implications of any explanations or hypotheses which are advanced One of the first considerations is an examination of the different ways in which the term *aging* is used

Use of the Term "Aging"

If one purports to be doing research on aging, he should be able to state in advance of his experiments what he means by aging, and each of the chapters touches to some extent upon the problems of defining the subject matter being discussed We can of course become too concerned with definition, which we are prone to do in the absence of data We might paraphrase Craik here and say that the value of a radio lies not in our ability to define it succinctly but in its ability to reproduce sound faithfully (Craik, 1943, p 2) Some moderate amount of attention, however, is justified to definitions of things to do with aging, since they are in a tangled early stage, but we should remind ourselves that we are not seeking rigid ultimates or trying to define the things we have to clarify by experiment The process of definition helps orderly inquiry, but it is not a replacement for it

The task of the investigator of aging in defining his subject is perhaps larger than is the case for many scientists, that is, the task of explication by which one replaces vagueness with precision Carnap has said that "the task of explication consists in transforming a given more or less inexact concept into an exact one, or rather, in replacing the first by the second" (Carnap, 1950, p 3) The prescientific concept "may belong to everyday language or to a previous stage in the development of scientific language " Although the initial concept, in this case *aging*, cannot be given exactly, it helps to make it clear by examples and by informal explanation The fact that, in order to replace a concept, one introduces precision by means of informal discussion and examples suggests that *aging* as a concept will not be defined once and for always but will over time become refined

A review of the use of the term "aging" in common speech and by scholars reveals some core meanings However, any attempt to define aging by consideration of the usual or core meanings would always, as does any definition, leave something out Thus for a particular purpose a narrow definition might suffice, recognizing, for example, that all persons would not agree that aging is a genetically determined pattern or that it is the accumulation of the effects of stress and a predatory environment In scientific discourse the core meaning of "aging" implies a determinate chain of events occupying a significant portion of the life span after maturity The use of the phrase "chain of events" expresses the notion of regularities Research on aging is the systematic inquiry into the regularities in the structures and functions of living organisms as they move forward in time in the latter part of the life-span What one takes as observed data and as observed or manipulated independent variables will determine how narrow a definition of aging will suffice

"Aging" usually means something closely related to chronological age but not identical with it, and most investigators would *maintain that they do not mean to include* everything correlated with chronological age when they use the term "aging" Indeed, so much happens to the aging organism that it may be hard to discern order or to maintain a sensitivity to the possibility that there is order in aging For this, as well as for other reasons, it is desirable for each investigator to make explicit the different arbitrary inclusions and exclusions in his use of the term In this *Handbook* 'aging' is used in two ways it is used, on the one hand, to explain phenomena and, on the other, it is explained in some studies "aging' is the label for the dependent variable and in others for the independent variable

Young and old men differ in many behavioral and biological characteristics, as the chapters to follow will detail It is not likely that anyone would seriously contest the statement that man and lower organisms have determinate life spans and show systematic changes with advancing chronological age It remains for empirical evidence to demonstrate whether there is a single mechanism or group of mechanisms *intimately related to the passage of time* which in a predictable way influences the characteristics of living cells and cellular organizations and which limits the life span

of ideas, this is a passing stage, and it may be that new terms will have to be introduced to satisfy different purposes of research Future refinements may even suggest that the term "aging" be dropped from scientific discourse and replaced by terms like "longevity," "senescence," and "antiquation," if sufficient specificity cannot be introduced in a term of such long standing usage The term "aging" has acquired a scientific and social significance which is independent of any particular scientist Thus an individual may not give it a specialized or narrow meaning without conflicting with established usage which regards aging as a broad process of post maturational change in the structural and functional properties of living things

If the organism or object itself does not change with time, then it does not age in the sense "aging" is used in this volume, despite the fact that one may have a continually decreasing population of survivors Figure 1 contrasts two hypothetical populations, one of which (*a*) has a constant

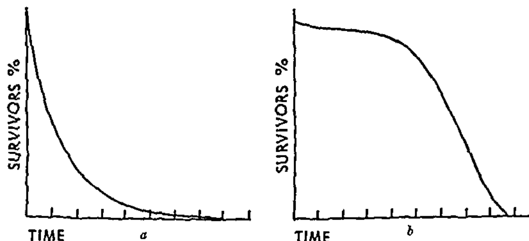


FIG 1 —Different types of survival curves (*a*) survival curve of a population with a constant rate of mortality (50 per cent per unit time) and (*b*) survival curve of a population exhibiting senescence (accelerating mortality rate) (After Comfort 1956)

rate of mortality, and the other (*b*) a mortality rate which changes with time An excellent example of a non aging or non senescing population, glass tumblers is presented in Figure 2 In general, glass tumblers used in a cafeteria do not change with time, although Comfort does point out that abrasions of the lip may accumulate with time and make the tumbler more susceptible to breakage, but this is probably a minor qualification The survival curves of water glass tumblers would show features similar to the survival curves of living objects if the tumblers showed a significant tendency to greater vulnerability to damage with time Differential exposure to damage with time or age would give a curve different from that shown in Figure 2 In general if given a choice, most people would pick the newest (less scratched) tumbler to use thus lowering the exposure to breakage with age A variable exposure rate with age is not usually included in the concept of aging although this point is not

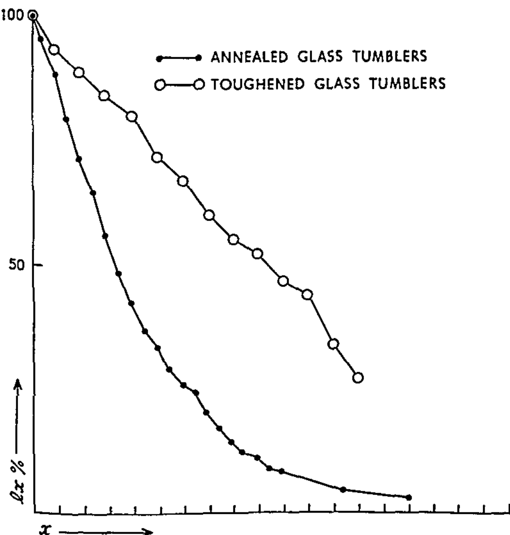


Fig 2 —Survival curves for cafeteria tumblers The two types of tumblers annealed and toughened, were presumably subjected to constant conditions of breakage throughout their life-span One scale division is 2 weeks for the lower curve and 5 weeks for the upper curve (After Comfort 1956)

so well established For some conditions it would seem that the exposure rate for humans drops with age, such as travel accidents, and infections, although the consequences per event may be increased with age

The Use of Age in Explanations

The concept of aging merges easily into the question, 'What are we trying to explain in aging?' Investigators are faced with "explaining or accounting for certain facts which are imbedded in chronological age Chronological age is one of the most useful single items of information about an individual if not the *most* useful From this knowledge alone an amazingly large number of general statements or predictions can be made about his anatomy, physiology, psychology, and social behavior Chronological age is a powerful index with which we can classify large amounts of data while seeking relationships Unless we can attach some significance to the role of time or age in the large array of facts in which it is imbedded, we might argue that the value of chronological age is limited to that of a pervasive filing index for data we cannot otherwise classify When our attitude shifts from chronological age as a useful index to considerations of a theory or explanations involving chronological age, there is an uneasy feeling that age or time may not be used like other variables in interpretations or explanations of events This raises a question about the role of time in explanation The properties of time are considered by Reichenbach in the next chapter, and it is pertinent to point out that the nature of time itself is a subject for investigation with emergent views The regular changes in form or appearance of organisms with age, however, indicates that time has direction for the individual (Medawar, 1945) Aging may be used to refer to relationships involving chronological age with the implicit assumption that such relationships are inevitably in transition to being explained by other variables without recourse to the use of the term 'age" Some investigators regard age as infinitely eliminable in favor of other variables In this vein *aging mechanisms* would be mechanisms described at an early stage of knowledge Proof of such a proposition would clearly involve us in an inexhaustible line of research

At any given stage in our knowledge an adequate description of an organism for most purposes requires a statement about the age of the organism An aging mechanism may be defined as an invariant relationship in which, with present knowledge, time cannot be excluded as a parameter from all transformations of that relationship It may be that with increased information about the classes of relationships which hold with age, some additional restrictions on the phenomena designated as aging may be useful Thus the form of the relationship and its direction in time may prove useful to restrict

It is a difficult task at present to draw examples of age relations of an invariant sort for the entire range of biological, psychological and social aspects Specifying an invariant relation may be most difficult for social influences since customs vary so much in successive generations Regardless of the content of customs if in all cultures at all times, old and young persons differ (e g , in dress, speech and other areas of deportment), age can never be excluded from an explanation of social behavior, even if the nature of the age difference is itself changing This amounts to the proposition that young and old adults differ because there have been secular trends which, if they continue, will always result in differences between old and young members of the population If the proposition is valid, the interesting implication is that there must exist mechanisms which accumulate the consequences of the secular trends either in individuals or in institutions or in both

Explanation and Antecedents

The *deterministic* position regarding aging is simply that if individuals and species

live different lengths of life or differ in some other attribute these differences are due to either the intrinsic nature of the organism or the environments in which they have lived If with advancing age there is a sequence of continuous changes eventuating in some outcome then a deterministic position would hold that we should be able to do experiments from which the later stages of the sequence would be predictable from antecedent early stages

The kinds of experiments we do and the kinds of theories proposed are influenced by our attitudes toward explanations in science Some investigators might regard determinism as unrealizable in their laws and theories about aging A rationalization for this position comes from the fact that our model for deterministic theories has been based on classical mechanics whereas the more recent laws of quantum mechanics are regarded as indeterministic The elaboration of this issue is a matter for philosophy of science but it is pertinent to consider the position of Ernest Nagel who does not accept the notion that quantum mechanics is indeterministic and its laws acausal He concluded after a discussion of the issues ' In short though the laws connecting micro-states may be statistical in their structure the laws connecting the macro-states that correspond to them may nevertheless have a strictly deterministic form (Nagel 1953 p 437)

The notion of level of observation is often introduced to express the difference in the form of theory and explanation depending upon whether one is dealing with single units or with aggregates Medawar went so far as to say that both Darwinian and Lamarckian views were appropriate depending upon the level of observation Inheritance that may be represented as Darwinian on one plane of analysis may be represented as Lamarckian on another (1957 p 79) This suggests we should not necessarily regard any theory of aging automatically as an indeterminate theory

Explanation and prediction for the investigator are almost indistinguishable (Hempel and Oppenheim 1953 p 322) Explanation does however, give emphasis to past events and predictions (future events), although the terms postdiction and prediction may be used with greater precision Both postdiction and prediction are attempts at explanation and may be stated as causal or deterministic laws—the assertion of general and unexceptional relations between events

Much of the data involving human aging and mortality are explained postdictively by statistical relations A variety of environmental conditions is regarded as influencing mortality and from existing data inferences may be made about causal relations which can be tested by prediction to future data or to other sets of independent data A postdictive statistical relationship in logical structure is deterministic if one assumes that manipulation of the antecedent conditions impl ed by the relationship would result in pred ctable outcomes

In aging as in other relations considered in science later events are to be explained by antecedent events and alternative sequences of events involved in explanations may be compared In general there is a preference to employ the closest antecedents of an explained event Remote antecedents allow for more misunderstanding since more events are contained in the causal chain Ag ng tends to involve us in discussions of remote antecedents with long chains of events described or implied in explanations of late life outcomes Remote explanation usually entails lengthy sequences of serially dependent antecedent events—or even a set of alternative sequences Both the length of the sequences employed and the number of alternatives contribute to an impression of complexity of explanation which in turn creates an aura of inelegance Many different biological psychological or sociological explanations may be advanced to account for the same outcome since they tend to select variables from different temporal positions with respect to the explained event. Such explanations are not contradictory provided that the events employed in the explanation are not contiguous in time and

that they do not imply a different chain of events Preference for a proximal point of regard varies somewhat among the sciences Biochemistry of aging usually involves a very proximal explanatory position, whereas the sociology of aging takes more temporally distant positions from the explained events

Evidence is presented in this volume showing that mortality rates are related to social class occupation and urban rural residence to name but a few relations These are more remote variables correlated with the death of individuals than those that the pathologist seeks to identify the latter wishes to identify the more immediate cause(s) of death An immediate antecedent biochemical event to death is not necessarily more valid in an explanation than is a remote social event By training we seek out familiar variables to use in explanation and these as determinants may have a characteristic position in the temporal order of antecedents Genetic physiological biochemical psychological and social explanations of a measured event tend to be samplings of events at different stages of a temporal chain The character of the explanation or law governing such events may change since an explanation based upon remote antecedents may be of a statistical character such an explanation may hold on the "average" but exceptions occur Involved in any definition, explanation prediction or control of a chain of events or regularities of aging whether it is a matter of longevity, chronic illness, behavior, or social adjustment, are variables of varying temporal and physical proximity to the observed event or process

Explanation and ease of intervention — The design of research is influenced not only by our background in a particular science but often by what we think would constitute a "good" explanation Behind the "good explanation" can lie notions about what is a proper and easy variable to manipulate Study of human genetics may be avoided because some feel that there is no point in studying and understanding something we cannot do anything about The narrowness of such a point of view is clearly exposed in chapter viii by Kallmann and Jarvik The point is being made that our estimates of the possibility of intervention influences our choice of experiments An explanation containing an acceptable variable that is easy to manipulate tends to be regarded as a better explanation than one involving variables difficult to manipulate

Concept of Aging in Experimentation

The previous section developed the idea that prediction—and explanation—rests upon the assumption of general regularities and certain antecedent conditions Few investigators specify what kinds of regularities they have in mind when they speak of aging, and the concept of aging is a most elusive one The elusiveness of the concept of aging makes many experimentally minded investigators feel that they cannot approach the subject with experimental techniques It is hard to know what the relevant techniques are to vague concepts This has been true also of the concept of development in the biological and social sciences as well (Anderson 1957 Hamburger, 1957, Nagel, 1957, Scott 1957, Sears 1957, Spencer, 1957, Werner, 1957) Dale Harris has said that "the concept of development has impressed scholars as being slippery, and of limited usefulness Few are those who attempt to master it in its many aspects" (1957, p 3) The concept of aging appears to be equally slippery, and in addition, aging appears to suffer a semantic blight Whereas development implies a positive or forward direction of the organism, hence "optimistic," the use of the term "aging" is suspiciously viewed as implying a belief in a systematic degradation of the organism

The experimental scientist may be wary of studying aging because by training and interest he wants to deal with interrelations among manipulatable variables He may be concerned with the ease of replacing "natu

ral aging' with laboratory aging—with the ease of replicating the supposed natural phenomena in the laboratory and replacement of natural concepts by concepts emanating from experimentation. Thus he may work on organisms of different ages, but the organism is only the host for the experiment, not a cause of observable phenomena. In the field of child development there are some researchers doing experimental work which happens to be done on children. If there is no intent to explicate a *process of development*, the children are experimental constants. An analogy exists to certain kinds of research done on older organisms. Another approach attempts to infer

ance of stages of development or aging.

Since old and young organisms differ reliably in many ways, much new information would be lost if students were discouraged from looking at the life spans of organisms on the grounds that age can never be manipulated. The point is whether there exists the possibility of a systematic theory of aging with an experimental as well as a descriptive orientation. Practically, there seems to be value in arraying facts by age of the organism, but whether we can place chronological age in an experimental setting and also use age in explanations is a different issue and perhaps an inexhaustible one. It may prove impossible to eliminate chronological age from explanations of certain facts about living organisms.

What Comfort takes for his task is explaining the changing probability of death as a function of age. His regularities are the "mechanisms of senescence," which for the human result largely in "the decline of some or all of the tissues thus deprived of the power of self renewal" (1956, p. 162). "The organism ultimately dies of old age because it is now an unstable system which is provided with no further sequence of operational instructions, and in which divergent processes are no longer co-ordinated to maintain function" (p. 189). Senescence would be thus a matter of progressive disorganization. "We have seen, in particular, that many organisms appear to have been provided by evolutionary selection with a 'programme' of development and function which is directional and finite, and that progressive loss of the power to remain in stable function occurs towards the end of that programme" (*ibid.*). He regards it as unprofitable to discuss the 'cause' of aging as to discuss the 'cause' of development' (*ibid.*). "Senescence is a change in the behavior of the organism with age, which leads to a decreased power of survival and adjustment' (p. 190). This view would have the organism progressing in time from an ordered efficient state to a disordered chaotic state wherein a variety of predatory influences or stresses might be the terminal influences on the individual life. Comfort's concluding statements imply that the organism loses its "programme" late in life and leaves the question of what regularities can be invoked in explaining why for adult organisms there is a constantly increasing probability of death with age. Comfort suggests that it may be the result of "the declining efficiency of the evolutionary pressure toward survival at different ages" (p. 189). Such a statement, while intriguing, requires some operational definition of that in the organism which is being selected and which is reflected in an altered probability of survival. To be useful, an effective rule for our explanations of such changes is that it should apply to more than one individual and represent a property which remains the same under a variety of specified circumstances. Thus we may ask of Comfort as well as of ourselves an example of a mechanism of senescence which is invariant to a set of transformations.

Properties of a System Which Ages

It is likely that there are certain external or internal events which are relevant to aging and the span of life which are registered by the organism and cumulated over

time It is not known whether these age relevant events occur periodically as programed events or occur aperiodically as random encounters The minimum properties of a system which ages appear to be two cumulation and irreversibility Irreversibility provides that events may proceed in only one direction There could of course be more properties of an aging system which would permit the prediction of later stages in a sequence from early stages however, the existence of the properties of cumulation and irreversibility necessitates the inclusion of time as a variable in describing the system Should these properties be found in all living organisms, then a general theory, either biological or social would have to include time in its system of explanation Most explanations found in the biological and social sciences do not include time as a variable Such statements are about systems at a point in time that is they are fundamentally cross sectional views

Irreversibility implies unidirectionality to events it does not imply degradation Labeling a phenomenon of aging as positive or negative, as evolutionary or involutionary as regression or differentiation or as integration or degradation depends upon the kinds of prediction we wish to make There is nothing inherently incremental or decremental implied by the concept of irreversibility, it imparts only a time direction

If irreversibility is a key issue at all levels of analysis—biological psychological and sociological—then attention should be directed at those mechanisms in the individual and in society which register and retain experience In the individual the nervous system and the immunological system appear to be specialized in their capacities to retain experience and mobilize it on future occasions and are correspondingly important for research on aging In societies relatively irreversible memories exist in bility may appear in cells as the accumulation of insoluble compounds If the organism has relatively indiscriminating biological registers, much of the fortuitous is accumulated It seems likely that students of aging per se will become increasing distinguished from other scientists by the amount of attention they devote to mechanisms which give the systems considered the quality of irreversibility Irreversibility may retain its essential property in some contexts by adding the qualifying word 'relative" At present we can conceive of irreversible phenomena for the life-span of a given organism which would be obviated for later organisms It does not follow that for example, because a search is made for irreversible mechanisms in the individual, life span or life-span content is fixed for subsequent members of the species

Distinction between Development and Aging

If the minimum properties a system must possess to age are irreversibility and cumulation, it would be difficult to distinguish *aging* from *development* The scientist and lay person alike however, tend to separate the first and second halves of the life span in speech, as though different principles were involved Young organisms grow rapidly at first, slowing as they approach the characteristic limits of form size, and function of the species (Carmichael, 1954) The limits are active ones, with continuing turnover of constituent elements, yet the adult vertebrate is remarkably constant in appearance and does not 'degrow' or retrogress to a more primitive form in late life Minor changes in bodily proportions occur in late life, of which the artist must be aware in order to depict a middle aged or old adult yet the proportions do not change as widely as those of the young animal We may recognize a kitten in an absolute sense by integrating three kinds of information size, form (and proportion), and behavior We might also be able to recognize the same

kitten as a young or old adult through some individual characteristics of appearance or behavior

In development organisms grow or change at characteristic rates toward some limits in size, form, and function, with the final state or limit representing a relatively steady state of forces (Medawar, 1945) *Form, size,* and *function* appear to have a durable or persistent quality in adult vertebrates Thus individuals change in appearance after maturity, but they change within some boundaries determined by the end of the early adult years Studies of aging might well include some portion of the developmental phase in order to determine the ages at which various limits are attained and some of the relevant influences Aging may be defined as beginning at the point in time when the forces of growth of the organism in size, form, and function have arrived at a relatively steady state

This definition lacks much specificity which would be useful in designing relevant experiments, but it has the interesting consequence that aging is not simply negative growth That is, we do not simply assume that aging is under control of the same variables leading to the development of the organism

The properties of systems which age are thus *irreversibility* and *cumulation* and limits of *size, form,* and *function* Curves of muscular strength in relation to age illustrate several pertinent points (Fig 3) In general, maximum strength is reached between the ages of 25–30 years After this age, however, the various muscle groups show differential decline In addition to sharing a general propensity to decline, the various muscle groups appear to be susceptible to specific influences, among them perhaps differential use Also the different studies of hand strength for example show declines varying by 100 per cent between age of maximum and age 60 While this may tend to confirm the impression that development of muscle strength is more orderly than is aging, longitudinal data are necessary in order to discuss the issues specifically, including that of the relation of decline to maximum level attained

Development, Aging, and Evolution

Pressures of selection, as on development (Bonner, 1958), cannot be regarded as significant in longevity, since the trait "longevity" does not appear until long after mating and reproduction have ceased Comfort also regards aging as outside the scope of evolution

> Senescence is not an inherent" property of the metazoa but one which they have on several occasions acquired as a potentiality, probably through the operation of evolutionary forces directed to other biological ends Senescence is typically an undirected process —not part of the programme, but a weakening of the directive force of the programme, an escape from coordination, combined with the arrears of processes which once contributed to fitness but are now running free [1956 p 190]

There seems to be something compelling about the idea that the characteristics of old animals, including longevity itself, can hardly have been subject to natural selection This, however does not take into account the possibility of two systems of inheritance, the nuclear and the cytoplasmic A genetic interpretation of aging and longevity in higher organisms will become more ambiguous if they, like paramecia, possess two systems of inheritance Studies of the effects of parental age upon the longevity of offspring are but one example of research which may show the limits of gene determined heredity within which transmissible adaptations may occur to circumstances of individual existence (Miner, 1954) To say that longevity is genetically determined is almost a truism, although it would be more accurate to say that the limits of longevity are genetically determined

Research is needed to test the view that aging in a previously determinate growing organism is largely biological chaos which proceeds by starts and stops marked by random assaults made upon an organism

which is only partially resistant and partially restorative because of previous assaults The organism becomes, in this view, diffusely vulnerable We can develop models for random assaults on individuals but there is a question whether the models will be useful in describing changes in the resistive and restorative processes Under some circumstances the exposure of individuals to environmental assaults may actually become less with age, although the consequences may become more severe For humans, at least, changes in resistive, restorative, and adaptive processes appear to comprise interesting aspects of aging for research

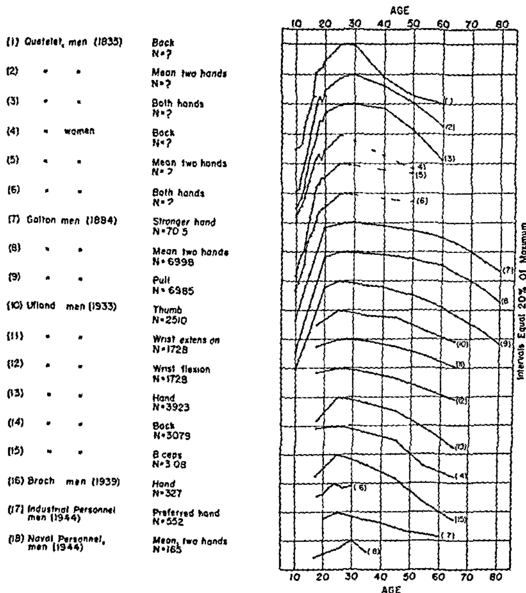


Fig 3 —Relationship of strength to age as found in various studies Curves show the differential decline with age in different muscle groups Values are plotted as percentages of the maximum Each curve is drawn to a different base line separated by a 20 per cent interval from the next (After Fisher and Birren 1947)

Models and Explanations

The particular aspect of the aging organism which interests us determines not only the kinds of studies we do but also how we think about it our models John Anderson (1958) has listed several types of models for aging (*a*) one-factor models where changes are traced to a single factor (e g hormone circulation or disuse) (*b*) simple machine models (e g wear and tear effects) (*c*) stress models (e g rare but serious overloads occurring during life-span) and (*d*) inverse development model (e g organism regresses along lines established during development)

If an elementary process model is assumed statements like these are made Aging results from (*a*) an orderly informed self destructive chemical mechanism and from (*b*) the failure to get essential materials from the nucleus to the cytoplasm These statements are in keeping with the traditions of the physical sciences which have made progress by studying selected elements of a total situation Some aspects of aging likely derive from integrative activity of the organism and it is for these that models are lacking and for which an elementaristic approach may not be productive

Research varies considerably in the extent to which it is *theory* or *model* or *data oriented* at present however most research on ag ng is data oriented This may be a reaction to the relatively untestable theorizing of earlier years but it may also reflect an inability to conceptualize processes of aging for whole organisms in such a way as to yield predictable outcomes for a variety of experiments Although research on aging is predominantly concerned at present with gathering of data it can be expected that broader conceptualizations and theoretical models will be advanced as a wider scope of variables is included in the explanatory matrix

A certain randomness to biological events in the last half of the life-span has impressed Comfort (1956) Landahl (chap iii below) Szilard (1959) and others An irradiation model is frequently mentioned as a useful one to consider aging particularly mortality data The attractiveness of an irradiation model lies in providing relations between a controlled but random insult with consequent non specific life shortening That is animals irradiated with low doses live shorter lives but die for the usual causes of late life as though the damage was diffuse and made the animal more vulnerable to the characteristic insults of its environment Statistical co-ordinates might thus be used to define the states of the organism In contrast one might attempt to define the state of the organism in terms of the values of parameters at several distinct points in time or over a continuous interval Both approaches would attempt to establish a unique correspondence between the definition of the state of the organism at one time and the state at some subsequent time The irradiation model however makes no statements about individuals but only about aggregates Statistical models may relate the number of survivors and non survivors of some event without specifying the state of individual organisms Propositions about the size of the group and the defined event are deterministic although not for the individual organism To establish a deterministic theory holding for individuals we would have to include specifications of the state of the organism at the beginning as well as at the end of the interval

Some emphasis should be given to the development of theories or models which prescribe some unique correspondence between the state of a living adult organism at one time and its state at any other subsequent time One difficulty in the development of models of aging is an inability to specify or define the antecedent state of the organism from which some subsequent state is predicted This reflects however a weakness of integrative biology at present we

cannot describe, measure, or specify the viability of a whole organism If we reject the idea that it is possible to describe a general state of the organism, which can be operationally defined, then we are left with the problem of describing independent sub states, any one of which can significantly affect the probability of survival In all the ones we will be faced with the necessity of operationally describing an initial state which exists as a precursor to some subse quent state It will be noted that time is used both to specify when the initial state, A, is observed and to measure the interval through which A eventuates in B, the sec ond state The question may be posed whether the initial description of A can be sufficiently enlarged such that the time of A, or the age of the organism at A, would not be required to predict the subsequent state B Is time or age necessary as part of the statement of subsequentness of state B? Biological states requiring fixed time inter vals for their eventuation are difficult to specify, but we should not exclude the pos sibility of intervening elementary states re quiring fixed intervals when they occur in viable whole organisms

Organisms do display regularity, biochronicity, in particular, periodicities are associated with reproduction (e g , cycles of fertility) In the case of development, un der the pressure of selection, there may have evolved elementary processes so regu lar in their occurrence that they are essen tially time defining for the whole organism, *biochrons* A biochron could be defined as an elementary biological process through which an antecedent state always eventu ates in a subsequent state in a fixed time interval despite large manipulations of var iables for the intact organism Organisms display marked biochronicity through a wide range of environmental circumstance, and we may question whether any neces sary relation exists between sidereal time and the biochronicity of complex organ isms For some purpose a biological process may be a more suitable time base for the organism than sidereal time

III Nature of Research on Aging

The contribution of an investigator of aging in part depends upon his ability to subdivide the total field into units amena ble to research with current methods and on his ability continually to link his results to a larger context Broadly speaking, the purpose of research on aging is to be able to characterize the nature of the older or ganism and to explain how the organism changes over time, that is to be able to make succinct statements explaining in creasingly large numbers of facts about ag ing individuals The role of the scientist studying aging appears to be no different from that in other fields of investigation In the process of integrating disparate facts into verifiable generalizations there are al ternating phases of conceptualization, frag mentation of problems and experimenta tion

Three Ways of Studying Aging

The study of aging may be approached in three ways (1) as a basic field of in quiry in its own right (2) as a source of experiments for hypothesis testing within the conceptual framework of established disciplines, and (3) as an applied field in which to develop and evaluate methods of meeting the needs of older persons As a basic field of inquiry the subject matter has a relatively primitive conceptual framework compared with established fields of inquiry like biochemistry, physiology, psychology, and sociology Since one must always have some prior knowledge in designing experi ments, recourse is made either to descrip tive studies or to experiments conceptual ized within an established science The study of aging tends, however, to empha size the unity of science rather than the compartmentalization of knowledge

Types of Study

1 Research on aging falls into four gen eral types Studies of longevity constitute

one of the more clearly recognized types in which length of life is regarded as dependent on a variety of independent variables such as genetic background, parental age, nutrition, and cultural differences In human longevity, inferences about the influences of the independent variables are almost exclusively limited to those derived from statistical analyses, whereas animal studies allow for direct manipulation of selected variables

2 Another type of study is concerned with differences with age in a broad range of biological, psychological, and social characteristics Interest lies not only in how long individuals live but also in age differences in particular characteristics Chronological age is used initially as the independent variable, but, as this type of investigation progresses, the resulting explanations do not usually include age or time Differences associated with chronological age tend to be looked upon as unexplained differences, and age related phenomena are considered only as sources of new information for other ways of systematizing knowledge

3 A third general type of study is concerned with problems of how a complex living organism moves forward with time Interest lies in what might be called the properties of "chronicity" of the organism The biological and behavioral chronology of the individual involves phases or stages of development and aging such as pubescence and menopause, which have a distinct constellation of characteristics The research task is to discern, within the range of individual difference in time of appearance characteristic events or sequences Time or age appears in explanations resulting from such studies, and the general implication of the approach is that any statement about living organisms has to be qualified in terms of the age of the organisms in mind

4 A fourth type of study is concerned with the historical aspects of the experience of an individual or group Thus human biography attempts to reconstruct the experience and trends of individual lives and is much concerned with what is unique in experience in the path through time Hypotheses derived from biographical historical studies can be tested in predictive longitudinal studies the purported consequences of selected types of experience can be predicted and individuals followed This type of study includes an identification of those [illegible]

Interest lies in identifying those aspects or patterns of the individual which will remain distinctive of him over the life span

These emphases on length of life chronology of events or age-associated changes have an effect upon research design and methods For example, if we adopt the view that any age difference is an unexplained difference, we might say that we cannot study the adult organism without ruling out the effects of disease, since it may be influencing an observed difference We are involved here in a circularity although a diminishing one, since almost all diseases of the adult organism themselves show an interaction with age Thus disease may not be studied without respect to the age of the host It is possible that we might choose to regard age in this context as standing for everything else we ought to know about the organism that is related to the disease Chapter xi, by Hardin Jones, indicates that disease-age interactions are being increasingly studied and, whatever our point of view, we should be alert to new inferences about age relevant properties of the organism

It is not unreasonable to expect that some classes of function may show evolution or increased differentiation at a time when other processes show involution Although both gains and losses in function may occur with advancing age, most published literature about postmaturational changes is concerned with analysis of decrements Value judgments may enter into a different emphasis placed upon studies of increments or decrements in function, particularly in the psychological area, where

an "emphasis on the positive" may appear to be more supportive to the aging individual, but studies of decremental changes need not imply inevitability Our strategy in picking and designing a research project on aging should be less influenced by what is currently a positive or negative approach than by longer ranged values including unforeseen benefits from the likelihood of gaining systematic information

Three Kinds of Aging

Closely related to studies of longevity is the problem of developing an index of physiological or biological age By means of measurements of the individual at one point in time, or several in a longitudinal study, the problem is to assign him an index number which would reflect his position on a continuum between birth and death better than would chronological age alone The kinds of measurements which would enter such an index would be most interesting It is not likely that all changes in the aging adult are related to how long the individual will live Thus some investigators may reasonably question to what extent selected psychological changes associated with age may be independent of biological factors known to be more closely related to length of life Man is a talking, thinking, social person but he is also a biological system with a species specific life-span

There is the general query throughout this volume of whether there are sequences of states or orderly patterns of change in the many biological, psychological, and social aspects of man which are so closely associated with his chronological age that they can be called "aging" A related question is whether, if such orderly patterns exist, they are at all related to one another Man as a highly developed organism may be differently described from different scientific viewpoints, and we might speak of the *biological*, *psychological*, and *social ages* of an individual The implications of each of these ages are somewhat different In the first case, *biological age*, one of the intents might be to designate the position of the individual along his life span—to designate his capacity for survival Thus viewed, biological age would be correlated with chronological age, but also to some extent it would be independent of it, since it must also correlate with the life span of the individual Such a measure of biological age must be able to predict with a smaller error the residual life-span of the individual than prediction based upon chronological age alone Tamplin (1959) described a method for evaluating physiological age in relation to mortality rates Longevity is only one aspect of biological age, but it is perhaps the most reliable one

Psychological age can be used to refer to the age related adaptive capacities of the individual A measure or index of psychological age would be based upon both the achievements and the potentials of the individual Like biological age, psychological age can be thought of in terms of a number or index which summarizes the position of the individual in a multidimensional space Presumably, a measure of psychological age would correlate highly with chronological age and also, but to a lesser extent, with residual life-span or biological age From a measure of psychological age it should be possible to predict, within some error, the capacity of the individual to adapt to familiar as well as unfamiliar environments Psychological age may also be regarded as a measure of the capacity to modify the environment

A measure of *social age* presumably would also be related to chronological age, somewhat to psychological age, and to a lesser degree to biological age Social age would refer to acquired social habits and status—to the individual s filling the many social roles or expect ... his age in ... cial age m ... composite index to the individual's performance of social roles It is obvious that these concepts or ages overlap somewhat, thus the capacity to lead alternative social roles is jointly a psychological and a social aspect of aging

It is a matter of considerable importance how much the biological, psychological, and social aspects of aging are interacting

Development of Age Scales

Admittedly, the concepts of *biological, psychological,* and *social age* are abstract, but they are not necessarily more abstract or less amenable to measurement than other concepts related to the circumstances of man's life-span Since our statistical methods are sufficiently well developed, we could, if we chose, select that combination of measurements which yields the highest correlation with specified criteria in the three areas of biological, psychological, and social age In the case of the narrow index of *biological age* described, the criterion is simple—length of life Interest is concentrated on which measurements have highest predictive value of residual life span If, for example, there are a great many predictable but independent factors any one of which can terminate the life, then a mean value would be of little use That is, a mean value describing the individual's position in a many dimensional space would have less predictive value for length of life than would the occurrence of a single extreme value in any one of the many dimensions If this were found to be so, it would imply the unlikely fact that there were no contingencies in the probabilities of dying from various causes The questions here are rather straightforward conceptually, although available data may not be in usable form Diseases leading to death are evident states which reasonably might be predictable from measurements of precursor physiological states Thus the research question is pushed one stage earlier in time What are the contingencies among physiological measurements of aging persons prior to demonstrable disease? It is a matter for research to demonstrate whether or not there are general contingencies among diseases with age and in precursor physiological states in relatively healthy persons of different ages At present, chronological age is our best general index to the residual life span of apparently healthy individuals If some combination of physiological measurements will predict residual life-span better than chronological age, presumably from the nature of the composite measurements, we could infer something about the mechanisms involved, and a further line of research could be developed which would attempt to alter the time course of these mechanisms

Psychological age and *social age* tend to be more abstract than *biological age*, since the rather specific criterion measure, length of life, is less pertinent. Thus psychological age should be expected to be closely related to measures of adaptive capacity, and the task consists of identifying and measuring those aspects of adaptive capacity which show a change with chronological age In comparison with psychological age, social age has the additional criterion of the extent to which the individual has acquired or performs the various social roles which his society and his immediate social group expect of a person of his age The emphasis in psychological age is on the *capacity* to adapt, whereas in social age the emphasis is on the *social output* or *performance* of the individual in relation to others Since interpersonal relations are largely mediated through the use of language, we would expect that social role performance may also improve with age, whereas the adaptive capacity of the individual, as in the rapid recognition of danger and the mobilization of effective responses, may decline Viewing the individual in terms of his social age, we are faced with an organization of habit patterns which may be judged according to their appropriateness in some group The individual may be simultaneously viewed in terms of psychological age or the processes by which he acquires, maintains, and modifies the habit patterns

Hierarchy of "Ages"

In an expanding inclusiveness each index of aging described embraces the previous

one but adds new aspects as well, chronological age being relevant to them all Beginning with longevity and chronological age, we first subsume them under the concept 'biological age,' which may be empirically related to a cluster of measurements yielding a better prediction of residual life span than chronological age alone Biological age is in turn partly subsumed under the concept 'psychological age,' which is concerned with the capacity of the organism to adapt At this level survival is no longer the sole important element, how well the individual adjusts to changing environmental conditions also demands attention At the next level, *social age*, not only elements of survival and adaptive capacity but also the new aspect of the social roles of the individual are included If we were to pursue an exhaustive series of investigations implied by the derivation of age scales or indexes of aging, it might be found that social age would be related to chronological age to only a small degree This is to say that survival and some minimum level of health and capacity are necessary to subserve behavior but are not usually the limiting or sufficient conditions determining the social role performance of people Although the concept of "psychological maturity" is supposed to refer to a general characteristic of individuals, there may not be a general trait, and "maturity" may be specific to situations We would not be privileged to speak of a general trait of "maturity" if *evidence indicated* that adequacy of behavior is situation specific Similarly if the adequacy of performance of one social role is unrelated to the performance of another, the concept of *social age* does not have much predictive and heuristic value it would merely express a summation or mean adequacy in unrelated behaviors or social roles These are matters for research and evidence, attempts to derive indexes of biological, psychological, and social age do not, however, bias against the finding that aging might be marked by specificity of changes rather than by changes in general properties of individuals If research should show that the various biological, psychological, and social changes of age are relatively autonomous, we should drop the linking word 'age' and resort to narrower non-overlapping terms to designate the various aspects of individuals which change with age Furthermore, it would imply that effective research on aging could be more narrowly conceived

IV Research Design

The evolution of an investigator's research on aging often moves from the finding of a trait or characteristic which changes with age through a second *stage of* finding out what factors covary with it and finally, to a stage of manipulating the isolated dominant factors A study in which the investigator attempts to modify a relationship by perturbation or *manipulation* is more efficient than the study limited to a "natural experiment" or passive observation of the relationship as is *often necessary* in man Although non intrusive observation is not the most efficient *method of* research there are many kinds of relationships which we could not for ethical reasons perturb in man and yet are also not amenable to research in animals However, *there are* usually more ways of studying an aspect of aging than an investigator can avail himself of because of his particular scientific lineage He necessarily approaches a topic with selectivity in his prior factual knowledge, experience with particular methods of gathering data, more or less *familiarity* with statistical techniques, and also biases in what constitutes "important" and "good" research Even if one is confidently, and perhaps justifiably, addicted to a *line of* research, it is helpful to know what the "line of research" consists of *in contrast* to other ways of studying the same topic

Cross sectional and Longitudinal Studies

The basic method of the study of aging is the longitudinal method, if we wish to

study age changes in individuals, we should follow individuals in time Cross sectional research on aging is a compromise or substitute for the ideal longitudinal study Since longitudinal studies have practical disadvantages, investigators often use cross sectional studies if the increase in error can be tolerated The practical disadvantages of longitudinal research have been described by Jones (1958) and are of several types involving the (*a*) investigator, (*b*) subjects, and (*c*) support

From a research point of view a 10 year period would seem to be a reasonable length of time to study aging in individuals Yet this can be a long time in terms of the time perspective of the scientist, and to wait 5 or 10 years for results is a greater procrastination than many investigators can tolerate Longitudinal research has administrative problems of keeping a professional staff together for long periods despite loss due to illness, change of position, and slackening of interest In the case of the young investigator, his career advancement may require earlier tangible evidence of achievement There is thus a professional risk involved for the research worker in addition to maintaining enthusiasm while deferring results for long periods One method of meeting some of the problems is to intercalate cross sectional studies on alternate years In the off year, issues growing out of the longitudinal study can be investigated rather quickly as well as meeting some of the motivational problems of the staff

Not only must the staff be kept intact, the population of subjects must be maintained Subjects move, get sick die, lose interest or become unsuitable for study for unpredictable reasons If the subjects are volunteers, there is a question whether their initial 'altruism' will grow or diminish over a decade It is likely that more effort has to be expended in longitudinal studies to cultivate and maintain subject interest and participation Subject attrition must be anticipated and a loss factor must be added to the size of the initial population

Antiquation of methods in longitudinal research can prove a hardship to the investigator The types of problems and methods selected in one decade may be obviated or dismissed by another In some instances 'satellite cross sectional studies may be carried out to determine the relation of the older to more contemporary measurements Other than to be aware that it might happen, this is a problem which cannot be specifically anticipated Institutional support may change over a decade, and the investigator contemplating longitudinal research may want to determine if the same facilities would be continuously available over a decade Even 10 years is a long commitment for many institutions for budgets, space and interest Merely the space for record storage and maintenance can become a difficult issue The above problems should not detract from the fact that the longitudinal method is the ideal method of studying human development and aging A cross sectional study may be accepted insofar as it may yield comparable results within some tolerable limits of error

Patterns of Aging

Cross-sectional research may mask individual patterns of aging Consider an example wherein changes occur in bursts If the population is averaged by age groups, a smooth curve may be obtained which epitomizes or reflects the time course of *no* individual If, like in development, stepwise changes occur, this important information is lost in cross sectional analysis Inferences about the form of the relation of chronological age to the trait studied are tenuous when based upon cross sectional studies The validity of cross sectional studies is limited to questions of whether age differences exist

One of the most difficult methodological problems is the study of pattern or types of aging There may be in aging as in child

development, patterns or clusters of relations typical of individuals, and we might raise the question of whether there are recognizable types or patterns of age changes in individuals such as early and late aging which divide them into subpopulations While personal experience or intuition may suggest that there are individual patterns of aging, the methods used to verify the existence of distinct patterns is not clear A relatively simple question is, "Is the rate of physical growth and the level attained related to the vigor and duration of adult life?" While it may take a long time to secure pertinent data to such a question, the relationships are simple If we ask, however, if patterns of development of mental abilities, physical growth, and social relations are related to patterns of aging, it is clear before we can answer the question that we must define a pattern and how we measure it operationally Basically, we must determine whether or not the indexes representing the measurements are from a single distribution Before we can speak defensibly about the existence of types or patterns, we must have shown the null hypothesis untenable —that the values cannot be regarded as random samples drawn from a single population The issues can be seen more clearly perhaps in the example problem of separating a random collection of tree leaves If we were given a basket of leaves to sort, we could separate, after just a little experience, oak, elm, catalpa, poplar, ginko, and other leaves These are reasonably separate types, and, even without prior knowledge of the types of leaves, a mutually exclusive system of classification would [illegible] Suppose we ask whether regional differences To answer such a question, we would have to resort to some system of measurements in order to characterize the leaves (e g , size or area, length width ratios, and number of serrations) The distributions of measured qualities could be examined for the homogeneity From measurements on an assortment of leaves the investigator would be expected to develop the concepts of the types and indicate the number of independent types of leaves and the subtypes

It is unusual in human research to have the existence of types and subtypes supported by statistical evidence Frequently, extreme or dramatic cases are selected which are presumed to epitomize a type or class without offering evidence of the class itself Dramatic cases may actually be extreme cases in a continuous distribution To be rigorous, we should not speak of patterns or types of aging or of development unless we can show that it is a necessary consequence of rejecting the hypothesis of a single distribution of relevant measurements Many important problems lie in this area, and methodological advances may be required before a single investigator can cope with the problems of data analysis and tests of significance

If we have a number of measurements on a group of subjects, it is possible by means of analysis of variance and other methods to determine if the interactions between subjects and measurement is significantly greater than we would expect on the basis of an estimate of error (T W Anderson, 1958) If chance as an explanation has to be rejected, this still leaves the problem of discerning the patterns and subjecting them to separate tests of significance In the case of aging, or development *time* would have to be added as an additional variable The question becomes "Are there distinguishable patterns of measurements on individuals as they change with age?" Viewed statistically, the problem is one determining how many classes of individuals is it necessary to postulate in order to account for the range of subject, measurements, and age interactions

Because of the almost insurmountable problems of data gathering and data calculation, investigators have occupied themselves mostly with analysis of types within a single dimension such as body size, although with advanced computers broader

analyses appear practical It seems plausible that there are clusters of age changes in appearance, body chemistry, mental ability, and emotionality which differentiate individuals into distinct life-channels some of which may be prodromal of disease and others of which may be indicative of a long vigorous life Empirical demonstration of patterns of age change may be a several stage procedure, with an emphasis on the validity of the patterns in replicated studies The issue may be expressed in the question What are the forms of aging and how are they distributed in the population?

Differences between Generations

Both cross sectional and longitudinal studies may be confronted with questions about differences in populations of the same age in different 'generations' Successive generations have grown taller and heavier, and it is reasonable to suspect that many differences between young and elderly persons are not due to aging but to differences arising from shifts in nutrition, nature of the physical environment education, public health and attitudes Adolescents today are not in all respects like adolescents three or four decades ago Nor are these teenagers 50 years from now, likely to resemble in all ways the current population now over 65 Generational differences are not entirely obviated by longitudinal study per se It is conceivable that the rate of aging for many characteristics will be influenced by shifts in the age of onset of puberty, rate of growth and nature of the environment

In the last 100 years man's muscle power has tremendously decreased in importance He now controls his environment largely by use of other energy sources than his own 'horsepower' The consequence of this low energy output for well being is not clear but it is suspected that this and other marked changes in activities must have an influence on our physical and mental well being and the ways in which we age

Most studies will contain mixtures of age trends and generational trends It is possible that generational differences will maximize some and minimize other age differences Perhaps more research will be done reporting age specific data by cohort groups so that the two trends can be separated The efficiency of longitudinal design may be increased by comparing present generation young persons on the same measurements as the previous generations being followed longitudinally An ideal solution would be continuous longitudinal studies in which new young subjects were being added continually Put in terms of the above issues the question may be asked whether individuals followed over their life span today will show the same manifestations of aging as did previous generations

One way of identifying possible differences between generations is to compare present samples of the population with earlier studies or with data on file in various institutions Many child research institutions of previous decades have physical psychological, and social data on file Students of aging might well capitalize on the existence of these early records and secure longitudinal data on subjects studied as long ago as the 1920's There is no accurate way of knowing how much valuable information for follow up studies exists in the files of our child research organizations Some notion of the available data may be secured from the institutes of child research which have been in continuous existence for several decades Also an examination of the literature published in child research 30–40 years ago will help identify pertinent subject matter studied and perhaps help to identify the institutions which have intact data

Comparative Studies of Aging

One of the most useful ways of finding out whether a relationship is an invariant one is to study it in different cultures or in different species A comparative approach

is beginning to be recognized in both biological and psychological studies of aging Comfort (1956) has reviewed the attempts to relate length of life to attributes of different species of animals

One of the few cross cultural analyses of the psychological aspects of aging is seen in Figure 4 which presents the results of ilar for the two populations While longitudinal studies may require qualification of the comparison and the inferences which may be drawn the curves are an interesting example of a cross cultural analysis of aging

It is not necessary that the primary mechanisms of aging be the same in all

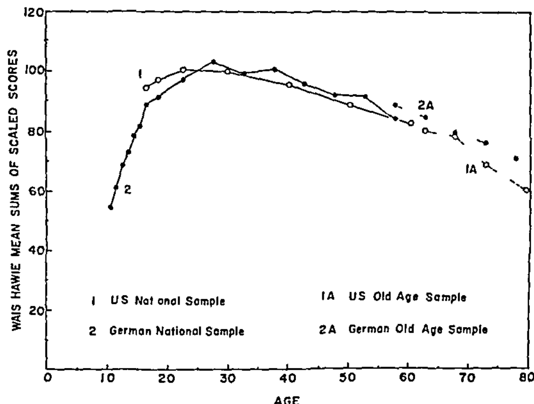


FIG 4 —A cross-national comparison of scores on an adult intelligence test and age Results are taken from the United States samples with the Wechsler Adult Intelligence Scale (WAIS) (Wechsler 1955) and from the German samples with the translated test (HAWIE) (Wechsler 1956) The German old age sample is from Riegel (1959) Both versions of the tests are adjusted to give a maximum score of 100 between the ages of 20-34 years.

a test of adult intelligence given to the United States population and the German population The test the Wechsler Adult *Intelligence Scale* was translated into German and the scores were adjusted to give a maximum score of 100 between the ages of 20 and 34 years Thus the same maximum level (i e 100) in the curves is without significance The change from this level is not so restricted and is remarkably similar species since each species has undergone a different selection process in evolution We should necessarily seek not *the* nature of aging but the variety of ways it is determined and expressed among organisms We may also compare the nature of aging among the species by analyzing what can reverse it It may be that different limiting factors exist among species and hence are related to what will reverse the limitation

We could also compare species on the basis of age changes in adaptability to environmental change

There is also the desirability of studying aging in relation to the differentiation of the species or culture If we can array organisms on some scale of least to most differentiation, then characteristics of aging might be examined for dependence upon the extent of differentiation of function of the system in which it is studied

Most laboratory strains of animals have been inbred for characteristics desirable at an early age, and little attention has been given to the later life-characteristics of the same animals Selection and inbreeding for desired early life-characteristics may have unknown consequences in later life (e g, the animals may die rapidly in a narrow age span of a particular disease) Until highly inbred strains have been examined for the later life-characteristics, "wild strains" of animals may be better in the sense that death would not be limited to one dominant cause

Types of Research Design

Two broad classes of research design may be distinguished *representative design* and *experimental design* In an experimental design the investigator feels that it is necessary for his purposes to extract a process or phenomenon of interest from its natural context and to place it in a controlled experimental or synthetic context in order to epitomize its nature In the representative design the investigator wants to study processes in typical or representative subjects, and perhaps in representative environments as well, in order to make generalizations about processes and relationships as they occur usually or "naturally" In practice, research on aging is often a combination of both types of design

The primary reservation which proponents of representative design have about synthetic design concerns the likelihood of a reported finding occurring in any real person living outside the experimenter's control Thus we may speak of a "physiological level" of a drug or hormone and raise a question whether an experiment lies within a normal physiological range, that is, whether the phenomena are likely to be found in non experimental contexts Analogous questions may be raised about psychological experiments, that is, whether the variables studied have magnitudes which lie within the range found for "real people living in natural settings" For example, many experimental factors can operate to limit length of life, most students, however, would be interested in aspects of the "usual causes' of death, not the unlimited class of all possible causes These comments should not be interpreted as implying that all research on aging should possess "ecological validity" or be representative of organisms and environments as we now know them The intent is to discuss the kinds of research as it will help to classify experiments and the kinds of inferences which might be appropriately drawn from the results

Brunswik has said about synthetic design that "some of the inter-combinations of variates may be incompatible in nature or otherwise grossly unrealistic" (1955, p 205) By contrast, Postman, in commenting about representative design, pointed out that in order to conduct some representative sampling, we have to know something about the universe to be sampled (1955, p 223) Thus, in order to study aging in samples of real people in natural settings, we have to know what features to sample Postman s comment is one of emphasizing the necessity for prior knowledge before doing representative research, whereas Brunswik's concern is with the process of extrapolation from laboratory studied processes to processes in "nature" As in most exchanges of this sort, the value of the discussion lies in confronting us with issues surrounding a general problem Because of its particular relevance to studying the implications of aging in man, *representative design* will be considered in some detail The nature and usefulness of

experimental design have been so well established that it would be redundant to treat it fully here, excellent references are also readily available (Fisher, 1949, Kempthorne, 1952, Wilson, 1952, Ackoff, 1953, Lindquist, 1953, Snedecor, 1956, Cochran and Cox, 1957)

Representative Design

Some aspects of aging in man will necessarily have to be studied in a representative design because it may be impossible for a variety of reasons to replace the naturally occurring events by manipulatable variables Representative research may also be desirable in order to secure information about the range of individual differences in some variable of interest and thus to enlarge our knowledge of the varieties of phenomena occurring in individuals living in natural settings, since not all these are predictable from laboratory investigations

In studying aging in man, several kinds of representativeness are involved *subjects, environments* (habitats or physical, psychological, and social settings), *processes, and time* The purpose of selecting representative persons, environments, processes, and time is to "learn something about how men, as we usually know them, age in environments as we usually know them' The most thoroughgoing representative studies are the ecological investigations in which the scientist observes from a remote vantage point

Ecological studies —The biological and behavioral ecologist wishes to observe individuals and populations without in any way disturbing them or their environmental relations Insofar as possible, the investigator avoids intruding upon the environment and observes, records, and analyzes information about individuals in the natural settings without in any way attempting to alter behavior The basic technique is "remote observation" of "naturally occurring' phenomena *At the other* extreme from ecological research is the laboratory experiment in which most variables are manipulated and controlled In studies of humans the ecologist would even avoid questionnaires or interviews, since this would introduce artificial provocation into the setting and alter the subjects People do change their behavior when they know they are being observed, and they may alter their language and adopt various "poses' when questioned Different results might be obtained from ecological observations about attitudes and behavior by and toward the aged than by questioning individuals Although for some problems it may be the most valid method the ecological approach has disadvantages The cost of ecological research suggests that the investigator give serious attention to the possibility of doing the study with a method involving somewhat more error but which may lie within tolerable limits The practical difficulties in ecological research concern the large number of investigators required to get continuous time samples, the masses of tape or other recordings which must be reduced to manageable size and form and the devising of a classification system for the observed events which will satisfy a panel of investigators and which will be easy to use Differences of opinion can readily arise over the classification of a unit of behavior or an episode Investigators must plan much in advance their methods of processing data and of data reduction and classification and include control of observer and classifier variables in the design Without such advance planning, the study may fail because the data grow rapidly to unmanageable size It has been said that recording of a single day's activities of one observed subject may require as many as seven to nine observers and involve three hundred pages of typed record

Research on aging is mostly concerned with achieving generalizations which hopefully will apply to many individuals in many situations in different eras Occasionally, *however, an investigator is intensely* interested in only one individual (ideographic approach) *Subject represent*

ativeness is not relevant, but what is relevant is representativeness of the sampled situations and processes or measurements, since these affect the kinds of generalizations which can be made about the single individual studied An investigator might also restrict his interest and wish to study only one type of situation (e g, one occurring once each year), leaving only representativeness of what is observed in the single situation to be considered Mostly, however, investigators wish to achieve generalizations which transcend individual subjects and situations, and they are concerned with measurements or processes and research designs which will yield valid generalizations of such scope

Representative settings —It is sometimes not clear what a representative sample of natural settings for older persons or animals would be like Although some emphasis may be placed on aging and behavior in natural settings, confusion may arise if there is a belief that we can describe a primordial scene uncontaminated by human influence For example, it is impossible to study senescent rodents in the "wild state," since old rodents simply do not survive the heavy predation in most "natural habitats" "Old' rats do not exist in the wild state It is perhaps best to drop notions of an ideal "natural setting" for our studies, since man and animals contrive to get themselves into most "unnatural' circumstances It is better to view *exemplar settings* as those in which an appreciable number of the population are found for appreciable periods of time People of different ages find themselves in different physical, social, and personal settings, and we are just beginning to build up a picture to make judgments about the situational representativeness of research projects (Kutner *et al*, 1956, Townsend, 1957) We know much more about the settings in which children are usually found than those of older adults With available examples of the ecological studies of childhood, such research on aging can progress more rapidly in this respect

Gathering information about the natural settings of persons of different ages may require continuing operation of research units in different parts of the country It seems reasonable that older persons in Minnesota in January will be found in different circumstances than in July, in both months they may differ in both physical and social circumstances from persons the same age in Florida Not only will seasonal climatic changes affect differentially the circumstances of people of different ages but seasonal work and social (holiday periods) patterns may also require sampling at different times of the year in various geographic areas In answering the question, "Where are people of different ages found?" elaboration of the descriptions of the settings may be made similar to those obtained in studies of the ecology of children (e g, number of people present, what skills are displayed, and what kinds of adaptations to the social and physical environment are seen) Such studies may also yield information about the kinds of adaptations individuals make to overcome the limitations of their settings and about the kinds of settings which facilitate the adaptiveness of older persons

Temporal representativeness —Secular trends in cultures and populations require sampling at several periods to check the validity of inferences It is likely that most public opinion polls are conducted during the work week, but, if religious attitudes are sampled relative to age, perhaps they should also be sampled on Sunday as well as on work days to check on transient attitudes Forms of speech, dress, and behavior are associated with different times of day, week, and year, hence what we observe must be stated in relation to when we observed it Temporal representativeness of attitudes and behavior can be studied with regard to economic cycles of prosperity and recession

In animal populations it seems likely that the position of older animals will vary in relation to secular trends in over- or underpopulation and the availability of

food In human societies prevailing attitudes toward employment of older workers will likely be differentiated with respect to economic cycles and the availability of employment It is of course only through replicated studies at different times that we can discover secular trends Despite the potential importance of secular trends in populations, little attention is given to temporal representativeness in design of research on aging Moment to-moment agreement is often considered as an aspect of reliability, and rarely are longer separations of measurements considered as something to be studied in terms of secular trend

In terms of research design the question may be asked of a study whether it provided an equal probability of the subjects' being observed at all times of the day, week month, and year Often of course the investigator wants to study a particular behavior, such as a working skill, which is displayed only at certain times of the day In contrast a composite picture may be built up of the content of a day for persons of different ages We have almost no information about the variety and duration of activities of the day for people of different ages A few of the daily activities of selected older persons are contained in the sample diaries presented by Townsend (1957) More information is needed indicating the flow of behavior throughout the day and the continuities and discontinuities in behavior, physical settings, and social contacts It would be helpful to know how many aspects of behavior are *temporal* and *setting specific* rather than *age* or *subject specific*

Viewed in its broadest context, in research design all members of the population should have an equal chance of being studied at all moments during their lifespan If *all subjects* do not have an equal chance at *all times* of their lives to be observed, selection has entered into the sampling either implicitly or explicitly It could be regarded as of trivial consequence to allow for an equal probability of night and daylight observation (e g , sleep and wakefulness) However, information about how much time in sleep is spent by persons of different ages might prove a useful fact as would information about nocturnal age related crime settings and accidents In other contexts biased time sampling of behavior may have considerable consequences for our generalizations about aging and behavior

Sampling and Subject Representativeness

Subject representativeness is a better known aspect of research design than setting or temporal representativeness and is usually discussed under the topic "Sampling" although the term "sampling" should apply to environments, processes and time as well as to subjects In studies of aging one does not include only retired university professors, since their favored mortality and intellectual characteristics do not make them representative of their age group A sample of retired university professors would contain a restricted range of biological, psychological, and social characteristics compared with the total population of that age

The methods of selecting a sample of older individuals are in general no different from those used with other age groups, although the characteristics sampled for will have some relation to age It is pertinent to point out that in comparative studies of aging, in addition to representativeness of individuals, we also have to consider the representativeness of the strain of the species or the species of the genus Since there may be strain and species specific aging phenomena, representativeness of the animals studied should be kept in mind We are ordinarily interested in obtaining a representative small sample of a larger population, since it is usually impractical to study the entire population of interest (e g , all persons over 65) The task is to select a sample large enough to give reliable results (and representative of the total population) and small enough to be feasible

for study and not wasteful of effort. The number and kind of factors involved in selection of a representative sample depend upon the purpose of the study—whether, for example we want to find the mean visual acuity, body weight, income or "intelligence" of persons over 65 or whether we want to find relationships between likely variables At present, research on aging is at a disadvantage because of the lack of adequate prior knowledge with which to plan studies of likely relationships Lacking a background of many studies we do not know what constitutes a representative small sample of older persons, this would not bother us however if every person in the population had an equal and known probability of being included But it is rarely possible to obtain a random sample of the population as would be obtained if every person could be given a number which could be drawn from an urn containing numbers for all persons of the population There are many practical reasons why this often cannot be done Table 1 contains a list of variables which are frequently considered in selecting subjects for studies or in analyzing data. Several major influences on the representativeness of samples of older persons will be discussed.

In the early stages of research interest lies largely in establishing what relationships exist, attention may later be given to the nature or form of the relationships There is a danger in using the *same population* or study to establish the existence of a relation and also the form In general it is a desirable conservative practice to predict the form of the relationship and subject it to a separate test by a replicated or more direct subsequent experiments The caution rests upon the possibility that the investigator will begin to interpret unwittingly error variance in the initial experi-

TABLE 1

CHARACTERISTICS OF HUMAN POPULATIONS OFTEN CONSIDERED RELEVANT TO INDIVIDUAL DIFFERENCES IN LONGEVITY AND AGING CONSIDERED FOR PURPOSES OF SAMPLING OR DATA ANALYSIS

Biological background
- Health
- Heredity
- Sex

Education
- Level attained
- Type

Occupation
- Type of work
- Length of time
- Work setting

Family
- Marital status
  - Single
  - Married
  - Divorced
  - Widowed
  - Children
- Present family

Ethnic group
- Nativity
- Family pattern
- Food customs

Geographic area.
- Place of birth
- Childhood
- Adult years

Housing
- Place
- Household composition

Recreation
- Number of activities
- Type

Religion
- Beliefs
- Activities

Social class
- Income
- Social roles

ment Replication is probably more necessary in the natural experiment or descriptive study than in the perturbation study

Institutionalization—About 3 per cent of the population over 65 live in institutions of all sorts Of this group about 1 per cent are in mental institutions A probability sample of all persons over 65 would thus contain patients in many types of institutions as subjects Often the method of selection of subjects allows either for an excess of institutionalized persons or for their exclusion It is obvious that both groups must be represented if we wish to talk about the entire population The alternative may be to limit the study to either institutionalized or to the non institutionalized persons accepting the fact that our generalizations will also be restricted

Survivors—Persons at about age 65–70 represent only about half of their population at birth If death occurs randomly a systematic bias in survivors would not exist but since they did not all die in accidents there is the possibility of a considerable selection process in the survivors of the birth population Survivors might be for example taller or shorter brighter or duller happier or unhappier than their non surviving cohorts Generalizations based on cross sectional studies have built in survivorship bias generalizations about average aging should be made with this in mind If earlier measurements on the subjects are available we may compare the present sample retrospectively with the total population alive at the earlier date The principle to be stressed is that studies of aging yield data on survivors of a larger earlier population which is susceptible to selective mortality

Health—At any time the number of children or young adults ill of a particular disease is usually a small proportion of the population (epidemics excepted) With older adults the incidence of chronic disease rises and there is a small likelihood that any person over 65 picked at random is free of all diagnosable conditions A representative sample of older persons and of older animals as well will contain many individuals with one or more diseases This raises the question of the extent to which a study of a physiological or psychological characteristic of an older population must attend to representation (or elimination) of disease states One point of view often espoused involves the concept of normality ostensibly the idea is that only normal older persons should be studied lest the results be an artifact of the presence of undiagnosed disease An assertive point of view would hold that if a trait is found to change with age in cross sectional samples it is not necessarily due to aging but to presence of disease There are difficulties in defining biological normality and also in deciding what course to take when the incidence of a disease occurs in a high proportion of the older population For many kinds of study it may be as necessary to know the health status as the socioeconomic status of a sample population in seeking out relationships with age It is conceivable that certain relationships will hold in the presence of frank pathology but not for lesser values of the independent variable There is the possibility that over a broad range health may vary without showing much influence on social and psychological characteristics but beyond a limiting value a relationship may be found

Typical variables—Educational attainment has been increasing so that successive decades have different levels of schooling What may appear to be an age trend in a study of a mental skill may indeed reflect a difference in educational attainment of the age groups compared Since different mortality rates exist for a number of variables (e g females and males urban or rural populations and body weight) these might be studied or controlled in samples of older persons

Subject procurement—Most studies use volunteer subjects and increasing interest is being given to the nature of volunteers In what characteristics are they different from their non volunteering peers? There is

not much evidence that older persons are more resistant than the young to participating in research studies, but, since many older persons have a heightened interest in their health, volunteers may constitute a biased sample in psychological makeup and well being The research interlude can often be a welcomed intrusion into the life of the older person and, once involved he co-operates perhaps more willingly than younger subjects One of the key items is the kind of initial information the person has received at the time he was approached to volunteer This information determines how realistic are the subject's expectations from the study and accordingly how comfortable he will feel in continuing as a volunteer once the study is under way

Controls in Research on Aging

A research study might be described as a controlled inquiry The investigator exercises several types of control, however by the selection of subjects environments, and time of measurements and by manipulation In studies of aging of lower organisms the investigator may manipulate or hold constant such variables as temperature, diet and activity A classical use of the term 'control' is in the expression "control group" Because of the great many influences which may operate in research on living things it is customary to include a control group in experimental studies In research on aging a number of control groups can be used to help reduce the likelihood of errors of inference, so that the particular phenomenon results from the experimental variable and not from artifact The characteristic control group is selected to be as similar to the experimental group as possible but remains untreated during the study

Experimental studies of longevity in animals usually show two mortality curves—one for the experimental and one for the control group Ideally, the two groups are selected from the same strain of animals are litter mates, and, until the time of selection were reared together When the experimental and control groups have a small range of individual differences, the efficiency of the study is increased by reducing the number of animals required or the magnitude of a difference which is judged to be statistically significant.

In human studies both one- and two-egg twins are often used to determine the effects of hereditary and environmental influences Co twin control, while very useful in studies of aging, is limited by the availability of twins for study Twin studies can be carried out by a few fortunate laboratories but most investigators will use *matching* methods to reduce the possible differences between their experimental and control groups

In research on human aging a young population is often an implicit control group The young adult group should be selected to be as nearly like the older population as possible, differing only in chronological age A problem arises whether *present* or *retrospective* matching should be used Consider the hypothetical example of a study of learning in a group of men 70–79 years old in comparison with a group 30–39 years old Suppose in this study the objective is to see if the older and younger men differ in their response to the distribution of practice In each age group there may be two or three subgroups differing in the amount of massing or spacing of the learning sessions Care would have to be exercised in selecting the subgroups within the younger and older, but this is a relatively easy task compared with matching the younger and older Suppose that one of the criteria is to be a measure of intelligence Should the two age groups be equated or should they be representative of the distribution of scores that might be obtained in the total population of that age? Here the investigator must decide whether he wants to match his older group on the basis of some estimate of what they were like when they were the same age as the younger group or on the basis of present characteristics Both approaches have pitfalls In the example of matching for in-

telligence there is the matter of what kind of test of intelligence should be used If a verbal test is used, an overestimate may be made of present intellectual capacity of the older men whereas if the groups are matched on the basis of a non verbal test an underestimate may be made of the older group This statement is based upon the differential changes in mental test performance with age (see chap xx below)

Another alternative is available to the investigator he may employ a pre experimental session using the same type of measurements to be repeated in more detail later Thus the older and younger subjects can be given a learning task and on the *basis of the results they can be matched for* initial level and rate of learning in subsequent studies of the effects of the distribution of practice Studies of age differences in the rate of experimental gain from a matched initial level can be made in many areas (e g , strength fatigue and psychomotor skills)

A form of control often used is that of partial correlation If it is difficult to select different aged subjects in advance according to some criteria, subjects may be "taken as they come' and divided into groups on the basis of additional information Suppose that the relation to be studied is age and mental ability but that the subjects cannot be matched for education and social class It is possible to examine the relation between age and mental ability by removing the effects of education and social class by partial correlation Removal of the effects of education by means of partial correlation is only an approximation to the "true relation," for example, between age and mental ability because there are many simultaneous aspects of education Masking the relationship are effects such as changing educational opportunity and changes in the educative process This is equivalent to saying, for example, that, since a 12 year attainment does not reflect the same influences today as 25 years ago a partial correlation is not a precise control Educational attainment represents some diffuse combination of differences in educability, opportunity, and effects of educative processes, analysis by means of a partial correlation is but a first approximation to more deliberate controls exercised by matching or manipulation

Because of complex secular trends, partial correlation is more suitable for examination of relationships within an age group than between age groups Between age groups there is the opportunity for many cultural changes which reduce the precision of the partial correlation method Consider the example of a study of the relation of strength and age which included the additional variable of stature Since successive generations have tended to be taller and heavier, the intent to "correct" the age strength curves based upon cross sectional studies for stature differences by means of partial correlation may be an overcorrection If between generations many positive but essentially unrelated changes have occurred in social cultural influences on man's development, then by partial correlation it is possible significantly to overestimate or overcompensate the influence from one source

The Role of the Statistician

Because of the extensive development and usefulness of statistical methods, it may be desirable to consider the statistical consultant as a necessity in most major studies of aging to take advantage of the most recent methodological advances—advances which the investigator himself would be unlikely to be aware of or skilled in The statistical consultant can help plan the experiment which will test the hypothesis in question with the minimum time effort, and use of experimental material His function is to help guard against "too much," "too little," or the "wrong kind' of data Another function of the consultant is to select the test of significance most appropriate to the conditions of the experiments He may question whether the assumptions involved in the statistical test are appropri

ate or are violated by the conditions of the experiment He may also direct attention to the precision of the statistic in establishing the level of confidence with which chance may be rejected as the most reasonable explanation of the results

Statistical methods became a practical tool for the research worker with the introduction of the desk calculator Electronic computers are now permitting more ambitious analyses of data although the consequences for research on aging have not yet been widely felt It seems likely that we will be changing our styles of data gathering and data processing considerably, although the statistician will likely be involved in most steps along the way

To be prepared for research in aging most investigators must master the simpler statistical methods While many will never need to employ complicated experimental designs in their investigations a knowledge of elementary statistics is essential for the efficient conduct of studies and for the evaluation of the published work Many excellent elementary and advanced guides to statist cal methods are available in biology (Pearl 1941) psychology (Gulliksen 1950 Guilford 1954) and sociology (Ackoff 1953)

The use of analysis of variance in research has proved extremely useful and has accordingly become commonplace (Fisher 1941 Snedecor 1956) It is a convenient method of separating a large variance into components and for testing statistical significance of the component sources The test is whether a source of variance contributes a larger proportion of variance than would be expected by chance alone Analysis of variance and covariance have some interesting applications to research on aging particularly for interaction effects wherein chronological age may interact with the variables It is worthwhile to comment in passing however about the origin and major applications of analysis of variance Much impetus for the development of analysis of variance came from agricultural research in which seed types and fertilizers had to be distributed over randomly selected plots of land The variables—seed types fertilizers and plots—are categorical and there is generally no interest in or possibility of arranging the variables in some order In contrast chronological age is a continuously increasing variable and one which may interact with other continuous variables Thus the form of the relationship is of special interest in the study of aging and is not ascertained by variance analysis In some instances it may be difficult to meet the necessary conditions for application of analysis of variances Thus it may be unreasonable to expect homogeneity of variance in different age groups In practice it seems unlikely to expect that only the mean and not the size or shape of the distribution will change with age If it did occur it would suggest that individuals changed at a constant rate If at age 25 we obtained a normal distribution aging may show individual differences with the consequences that a random variable is added to a random variable This would result in a normal distribution at an advanced age but one of larger variance If the rate of aging were related to the original level such as the init al level being changed by a factor multiplied by age or raised to some power function of age the variance would also change but the distribution would retain its normality Both the size and the shape of distributions may change with age and we may use non parametric tests of significance in circumstances where the characteristics of the distribution are not stable

There are so many conditions which covary with chronological age that it is difficult to make precise statements unless an obtained relationship is isolated as in a perturbation study or by convergence in a series of studies wherein increasing numbers of variables are held constant by sampling or stat stical control A pertinent example of the problem of covariance in studies of aging lies in measurements of psychological capacities and age One of the important covariants in the population previously discussed is education since the

level of educational attainment has been increasing in successive age groups The average attainment of young groups is slightly over 12 years (i e , high school), whereas for persons over 65 the average attainment is about 8 years (elementary school) Thus in the population as a whole educational level is negatively correlated with age

Factor analysis is a useful statistical tool in the early stages of a field when there is little knowledge of what conditions vary together (Thurstone, 1947, Guttman, 1954) In principle it is a way of analyzing common sources of variance among a large number of possible variables (Tryon, 1939, 1955) Graphically, it may be regarded as a way of discovering clusters of variables Its role will be most useful in the early stages of study wherein the investigator wants to get an idea of the "dimensionality" of the domain Subsequent study in general may be expected to involve detailed investigations of a limited number of variables from the factor analysis Factor analytic methods have been programed for electronic computer use, and many behavioral scientists will find them useful in sorting out common variables in a relatively unexplored domain They may also be useful in pattern analyses Factor analytic methods will generally not be attractive to the biologists although should a physiologist be interested in deriving an index of physiological age, factor analysis will prove useful as well as methods of deriving weighted components

V Aging and the Organization of Behavior

The purpose of this section is to discuss some issues of special concern to the investigator interested in age changes in behavior and adaptive capacity Time is not often considered in the analysis of behavior, although commonly mentioned in daily life, 'Time will heal ' In such circumstances we may question if time is operating only in the sense of an interval within which events occur It is not time per se which cures or heals but the occurrence of events On the one hand, the student of behavior of the total organism must be aware that with age the maintenance biology of the organism as well as the appetites and drives influencing behavior may change On the other hand, the social environment of the individual may change The behavioral scientist is thus involved in studies of diverse biological and social influences, and he becomes concerned over the extent to which the capacities and behavioral characteristics of individuals of different ages are determined by past experience, the present environment, and biological processes The interests of the behavioral scientist in aging raises basic questions about the determinants of behavior If we knew in more detail how behavior is organized, we would better be able to study aging, but similarly more knowledge about aging will help us understand how behavior is organized

The student of behavior will ultimately be faced with the question of explaining how the nervous system functions and the bases of behavior from a synthesis of our knowledge of changes in the elementary units—the cells Certainly, no mere multiplication of cell number by the characteristics of a single cell will tell us much about how the nervous system functions The brain for example, has been described as many organs rather than one organ, and we are faced with a necessity of finding ways of describing the hierarchical organization of the nervous system in addition to the description of cells

Study of a simplified system is generally a desirable trend in science, providing important properties are not lost, a serious problem for behavior Since man's behavior is determined by many influences (e g , genetic predispositions, learning and fortuitous events), it is difficult to know at what level of simplification important aspects of aging are lost

It is possible that behavior is organized more intermittently and is more determined by situation than other aspects of organ

isms If this is so, there may be greater discontinuities expected in explanatory principles from one domain of behavior to another It is difficult at present to discern the kind of explanatory principles and models required if a wholistic approach is advocated for the study of aging and behavior We might say that we would consider as many aspects of the organism as is necessary to explain a phenomenon, but this is an open ended statement, it does not tell in advance what we should or what we have eliminated from consideration Probabilities of behavior are perhaps our best form of lawful relation, although the employment of some teleological like concept of "adaptive economy" is sometimes invoked to explain why a particular behavior results from a constellation of circumstances To say merely that behavior is complex does not help us in our task to understand aging, the contribution lies in specifying the ways in which it is complex so that the complexities can be studied

Concept of Autonomy of Change

It still remains a matter for research to demonstrate whether there are common processes in the biological, psychological, and social determinants of the behavior of aging man One possibility is that the aging individual is a universe with many subsystems, each subsystem having the potential to terminate the existence of the whole but largely autonomous and describing an independent time course during the life span Even if a subsystem has the potential of limiting the life span of the whole, knowledge of the operation of the subsystem does not necessarily permit any generalizations about the general state of the organism prior to death If we knew that the organism is a loose confederacy of many largely autonomous subsystems each of which has the potential of limiting the existence of the whole, it would influence very dramatically the design of subsequent research It is also possible, however, that there is a high interaction of the vital subsystems In this case a statement about the probability of a failure of a vital subsystem would contain a contingency common to all vital subsystems The cause of death would in this case be a relatively minor incident occurring in a generally vulnerable organism This is to say that the cause of death would be one of many seeming accidents which could befall the organism, the essential or more important aspect being the general vulnerability of the organism

It is expected that in the near future descriptive and experimental studies of aging will give us some approximate information on the question of the degree of autonomy of age changes in the vital processes and behavior At present we do not know the relation of behavior or of the psychological and social subsystems of the organism to the vital subsystems controlling the life-span Although of direct concern to some biologists length of life would not be a relevant fact to be considered by students of the nervous system and behavior, unless the cause of death reflects some interacting antecedents in the organism

Although most aspects of the organism are in continuous flux or adjustment, they need not all be interacting Much of the biology of the organism may be viewed as vital or *maintenance biology*, necessary for behavior but not a determinant. In the healthy, normal human, only a small group of factors may be relevant at any given time to the behavioral output Most biological processes of the body can of course limit or determine function should unusual levels be attained Thus blood flow to the brain may vary through a range of values without influencing behavior, at some lower limit, however, it becomes the major factor governing behavior of the organism and ultimately deterioration and death This prompts the point that in aging it seems particularly important to keep in mind the *threshold* like quality of biological behavioral relationships—that they may hold only in restricted ranges of the variables

Concepts of Discontinuity and Adaptation

The concepts of discontinuity in behavior and adaptation are closely related If the individual shows adaptation then a new set of behavior determinants is contained within the individual manifold His new way of responding to the environment cannot be wholly predicted from his past behavior it may be unique for him and perhaps for the species as well

> Inborn diversity makes for versatility in evolution Every living species must provide not only for the present but also for what may happen to it in the future only those lineages survive to the present days which in the past were versatile enough to come to terms with their environment All organisms must have a genetical system as they must also have immunological and nervous systems which can cope efficiently with what has not yet been experienced —with what if they were sentient we should call the unforeseen [Medawar 1957 p 185]

The student of aging must continually be aware of the uniqueness of individuals and that man and other organisms possess a genetical system which keeps that diversity permanently in being By making and controlling his environment man avoids the pressures of selection yet his uniqueness *may show itself most clearly in his manner* of aging As man ages he becomes more like himself in the sense that he manifests his particular genetic disposition and the consequences of a unique set of cumulated experiences

Genetic facts set the limits within which the organism may adapt to environmental circumstance Within these limits adaptiveness is displayed at various levels of function from the biochemical to the psychological, and for research on aging there is not only interest in identifying adaptive mechanisms but also the consequences of their long term use We may question how the organism remains somehow stable and resists so many forces to transform it Or we may be interested in obtaining detailed descriptions of the mechanisms whereby the organism can continually adapt, some environments are likely facilitative in the sense of encouraging adaptive capacities As the organism progresses in time, it must recover from the consequences of environmental demands by the use of self repair mechanisms The adaptive organism will in the future incur less in the way of consequences from a similar event Thus the immunological system "remembers' a previous illness, with the result that a second infection may be met more effectively Similarly, the nervous system has a memory for previously successful adaptations, so that subsequent events are met more effectively Just as in the field of immunology questions of ' How much?' ' What kind?" and ' How often? ' may be applied to the conditions of experience for developing psychologically adaptive adults

Memory of a previous infectious disease and of a previously effective psychomotor response can be stored in a latent manner against the time when it can be evoked in adaptive responses of the organism The nervous system in addition to possessing the property of memory in the inactive storage sense also possesses the quality of anticipation, the organism can anticipate future situations and have appropriate responses at least partially organized in advance *This attribute of futurity which humans* have so distinctively, is of course enhanced by many cultivated environmental reminders and seems to be deeply involved in man s adaptive capacity However, anticipation of necessary future adjustments would be a helpless awareness if it were not for the organism s capacity to withhold or defer responses to proximal stimuli That is the adaptive organism must on occasions inhibit responses to present stimuli in deference to some selected and anticipated future stimulus Without the capacity to inhibit responses the organism would be always bound to the transient present humans in particular seem to be able to defer responses in accord with some long range anticipation or set Involved in many discussions of the behavior of older individu

als is the question of whether their behavior is more immediately stimulus bound in contrast with young persons. The question is whether present stimuli have a disproportionate primacy in older persons, and it is by no means settled that older persons are more rigidly bound to the present moment in their behavior.

Birren (1959, p. 160) has proposed on the basis of admittedly scanty evidence that older persons showed a reduction in inhibitory control over behavior. This is now recast and expanded as a more formal hypothesis that, all things being equal, the aged person shows a reduction in excitability of the central nervous system which is manifested in longer latencies of responses and in a relative incapacity to withhold responses. Such a hypothesis has heuristic value for many reported age differences in acquisition and extinction of responses, psychophysical judgments and speed of response in relation to stimulus intensities and many other kinds of behavior subserved by the central nervous system. If verified, the hypothesis would in turn need an explanation in terms of the structural and neurophysiological changes of the nervous system. A reduced capacity to withhold responses as well as the longer latencies of response, whether or not they result from a common cause, would impair the organism's capacity for adaptation. Long term programing of behavior depends upon the capacity of the organism to resist distractions—to inhibit responses to stimuli which for a particular goal may be irrelevant or semirelevant. At another level, garrulous or desultory speech contains the quality discussed here—the failure to inhibit associations or responses and display selectivity according to a pattern extending over an appreciable period of time.

The concept of *threshold* has two implications for the study of aging. First, it is likely that many relationships which hold near critical values, as for the moribund organism, may not be relevant to the functioning of the healthy adult. Second, variables in the older organism may shift to characteristic ranges, not found in the young, wherein new relationships between variables are found. Discontinuity in relationships may be more common to behavior than to other aspects of the organism. The existence of thresholds can result in intermittency of behavior in which a set of relationships hold only for a limited time period, perhaps minutes, perhaps hours, following this period a new set of behavior determinants is established. Thus viewed, behavior is considered to be governed by sets of determinants, each having different boundary or threshold conditions and which if met results in sudden shifts of behavior. The behavior or output of the organism in this view would be described as quantum like, and relationships as probabilistic in nature. Time-limited and quantity bounded relationships may hold for other phenomena in the aging organism as well as behavior.

Time Shifts in Determinants of Behavior

Man's activities are determined by mixtures of various biological and environmental influences. At one moment an individual may be acting primarily in response to biological drive and in other cases to a very cultivated motivation, such as viewing a theatrical production. The implication is that the behavior and motivations of normal individuals may be largely discontinuous: at one moment behavior is largely task specific or determined by the situation and at the next moment determined by some inner state. Without an estimate of the proportion of time spent in various activities or "emitting certain kinds of behavior," there tends to be no limit on the pervasiveness which can be imparted to particular selected variables. This leads to the suggestion that there is a need for some studies employing a kind of proportionate sampling of daily behavior. Under some circumstances, as in a disease, perhaps all the behavior capacities of the individual are diminished, whereas, in other circum

stances, the capacities remain but are simply not called into play because a particular set of instructions to the organism are being followed to the exclusion of all others A proportionate time sampling of activities would help to give some total perspective of man's behavior One may then hope to answer questions about what proportion of individuals' daily activity show changes with age

Sampling of behaviors as they are emitted in natural surroundings requires that we be able to classify that which we observe The range of possible behaviors makes the problem of classifying or cataloguing human behavior a difficult one No other animal nearly approaches man in the diversity of activities in which he engages The ecologists have been particularly concerned with the classification of observed behavior The point being emphasized here is that attention should be given to the proportionate amount of time individuals of different age spend in various daily activities (e g , the number of hours spent in sleeping eating and talking) The importance of a supposed determinant of behavior is in part related to the number of behaviors affected Thus the importance of a determinant is judged by its pervasiveness in the daily activities of an individual as well as the intensity of an effect within any particular period or upon a critical activity

VI Evaluation of Research

Most investigators will agree that judgments or evaluations about a report of current research are fallible Although history often shows contemporary judgment about a piece of research to be faulty, if not in gross error, contemporary judgments are better than chance, and we cannot defer to subsequent generations and avoid all evaluations for several important reasons Thus we have to decide whether or not to modify a planned piece of research in the light of a current article, since the article might point out serious limitations in the methods which were planned for use or may describe a new and more efficient method Furthermore, the article might reveal a conflict in existing interpretations which imply new experimental controls or point out a hitherto unsuspected influence in the type of study proposed This leaves the investigator in the position of either ignoring current reports or evaluating the contents and modifying his research accordingly Graduate students are expected to be able to evaluate critically the contents of a research article Seminars are often arranged for the purpose of encouraging the development of this skill by having the students systematically dissect articles and by asking the student, by virtue of hindsight, how he could redo the study to better advantage A keen mind can discern the issues in the written word, but it is only with the addition of considerable firsthand research experience that one can read between the lines and can temper a face value acceptance of what is said However, an outline of issues helps to focus experience and make the process of evaluation more orderly Anderson (1954, p 52) presented a useful outline for the evaluation of research which grew out of his experience as an editor, as a teacher of graduate students, and as a research investigator His material has been adopted and expanded in the outline below The outline summarizes many of the main points of this chapter Some aspects of the outline may appear obvious, but if the points are "good ' in addition to being "obvious," they may still add to the pressure for a more ideal state of knowledge about aging

RESEARCH EVALUATION OUTLINE

PROBLEM

1 Is the problem clearly stated?
2 Does the problem have a solution the way it is formulated?
3 Is it clear whether this is a normative study or survey or a study to test a hypothesis?
4 Is the literature of previous studies of the same or related problems adequately reviewed or taken into account?

Are the essential concepts necessary to an understanding of the problem defined?

6. Is the content of the problem so described so that it is readily apparent what is included and excluded from consideration?
7. Is the soundness or importance of the problem sufficiently developed so that judgments can be made about the suitability of methods?
8. Are the consequences of possible findings pointed out?
9. Does the author attempt to make a contribution to systematizing previous information?
10. If a hypothesis is tested, is the theory from which it results sufficiently stated so the hypothesis can be evaluated?

DESIGN

1. Was the design of the study planned and evaluated beforehand?
2. Does the design take into account all the pertinent aspects of the study: subject and materials, environments, manipulated variables or stimuli, measurements and observations, and statistical methods?
3. Is the design succinctly presented, as in a diagram, so that it can be readily understood?
4. Were alternative designs considered and the basis for their rejection given?
5. Are the compromises made with an ideal design described?
6. Is it possible for the design to answer the questions posed or the problem of the study?
7. Is the design an efficient one to solve the problem in terms of money, subjects, and time?

SAMPLING OF SUBJECTS OR MATERIALS

1. Is the sample adequately described?
2. Of what population is the sample representative?
3. Is the sample an appropriate one for the purposes of the study?
4. Were the subjects selected according to the design of the study and with regard to the statistical methods to be used?
5. Is the size of the sample adequate?
6. Was the sample collected for the purposes of this study or for some other purpose?
7. Are the methods of sampling described (after Ackoff 1953, Table 14)?
   a) Simple random
   b) Systematic
   c) Multistage random
   d) Stratified
      i) Proportionate
      ii) Optimum allocation
      iii) Disproportionate
   e) Cluster
   f) Stratified cluster
   g) Repetitive: multiple or sequential
   h) Judgment: quota

CONTROLS

1. What controls were exercised through sampling (e.g., twins, littermates, and matching)?
2. What controls were exercised by selection of settings or natural habitats?
3. What controls were exercised by experimental manipulation?
4. Were the conditions the same for all subjects or were adjustments made?
5. If controls were changed, were results analyzed with respect to the altered conditions?
6. Are there any important controls missing in the study?
7. Were any controls usually found in a study of this type absent, and, if so, was the absence justified?
8. Could any additional controls have been included which would have increased the efficiency of the study?

MEASUREMENTS

1. Are the techniques of measurements or observations adequately described?
2. From the information presented could the measurements be repeated by another investigator?
3. Are the measurements suitable for the problem?
4. Were the measurements or observations known to be sufficiently reliable for the study, or if new, was their reliability reported on?
5. Were calibrations of instruments, observer differences, and other aspects of the techniques described?

DATA TREATMENT

1. Are the methods of recording and the treatment of data described?
2. Are the statistical procedures described and are they suitable?

3 Are the tests of significance described and are they suitable?

RESULTS

1 Are the results or data adequately presented so the reader may verify the authors statements about them?
2 Are estimates of error provided?
3 Have the essential relationships posed by the problem been analyzed and tested for significance?
4 Are the results clearly reported in tables and graphs so that others may use the data or reproduce the results?

CONCLUSIONS

1 Does the author draw conclusions about the major problem of the study?
2 Are the conclusions clearly supported by the data?
3 Are important reservations or qualifications pointed out?
4 Are artifacts or spurious relations pointed out?
5 Has the author overlooked important aspects of the results?
6 Are necessary modifications of theory, current interpretations of data or practice pointed out?
7 Are the results interpreted in relation to other published information and are their significance for related fields pointed out?
8 Are the methods used in the study critically reviewed in the light of the obtained results?
9 Are the interpretations implications for future research and the development of new methods appropriate for the scope of the present study or do they reflect an over estimation or underestimation of the significance of the study?

VII Significance

One of the questions often raised about a study is whether it is 'a significant one" The term "significance" is used in many contexts as though it were a unitary judgment, whereas there are many criteria of the significance of a study Statistical significance refers only to the reasonableness of rejecting chance as an explanation of obtained differences The significance in the sense of the importance of the obtained difference for other purposes is still another matter Some aspects of importance are readily understood, like the social significance of a study for health practices and longevity, but others, like the usefulness of the data in disproving a hypothesis derived from a theory, may be of far reaching significance but may be less apparent There is the opportunity for many kinds of significant research, and in the diversity of our studies we should be increasingly explicit about our *problems, theories, designs, controls, methods,* and *analyses* of results Through consideration of these can we or future readers decide if an investigator has provided a firm steppingstone for going forward—a significant study

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II

The Place of Time and Aging in the Natural Sciences and Scientific Philosophy[1]

MARIA REICHENBACH AND RUTH ANNA MATHERS

I Distinction between the Subjective Experience of Time and the Objective Properties of Time

Subjective Awareness of Time

TIME AS A UNIVERSAL EXPERIENCE

The experience of time is one of the most intimate and poignant experiences which no human being can escape—an experience with which he comes in contact immediately after birth The baby's needs of food, elimination, and sleep manifest themselves at certain intervals and in a certain order and have to be taken care of Feeding schedules and sleeping schedules regulate to a large extent everybody's life from beginning to end, and our feeling of physical well being is closely related to them Later, play schedules and work schedules, however flexible, are added and permeate our whole life How often did we hear as children "It is time to put away your toys", It is time to wash your hands for dinner", "It is time to go to bed"

DIFFERENCES BETWEEN THE CHILD'S AND THE ADULT'S ATTITUDE TOWARD TIME

The child's attitude—In spite of his periodic needs, the child's attitude toward time is different from that of many adults He has hardly any conception of what it means to waste one's time or to budget one's time Since there is so much of it, why be stingy?

Gradually, the child becomes aware that time can be measured, he learns to tell time, the hours, the minutes, the seconds, the names of the days of the week in their periodic sequence, and the names of the months The child is proud that on a certain date he always becomes a year older Becoming older means growing up, and growing up means more freedom and more power, access to more adult activities, and recognition of status The "coming of age" is eagerly

ceremonies, festivals, and the bestowing of new rights and privileges, on the one hand, and of new duties and responsibilities, on the other

The adult's attitude—Later in life the emotional reaction to time usually changes *The adult often wishes to start all over* again, he has regrets over wasted time [illegible]

dreaded

TIME AND AGING

In time our bodies deteriorate, our minds become less alert, and the satisfaction of our basic physical needs is less easily achieved because of illness Our health is often a function of age "Aging" is obviously a term per

[1] Sections III and IV are based on and follow closely Hans Reichenbach *The Direction of Time* Quotations and reproduction of Figures 3–7 are by kind permission of the publishers University of California Press Berkeley and Los Angeles

taining to time The experience of aging contributes to our awareness of time We "age" as soon as we are born, there is no reversal of this process or any exception, all kinds of patent medicines or the epithet "ageless" applied to some persons notwithstanding No one is exempt from this process, the experience of time by human beings is universal

PSYCHOLOGICAL ATTITUDES TOWARD TIME, INDEPENDENT OF AGE

Distortion of the time metric —We see how closely our physical and psychological states are related to age and how they change when we become older Yet subjective reactions to time are often quite independent of age For instance, our personal estimates of time intervals tend to be unreliable because in certain situations they are relative to our physical states or emotional attitudes It is a familiar experience that time hangs heavy on our hands when we are ill and in pain, that an hour may seem an eternity to us when we are waiting for some news about the safety of a beloved person, and that time drags when we are bored but cannot escape On the other hand time flies, sometimes when we are happy, in love, or on a trip, sometimes when we anticipate a dreaded event that we should like to postpone, such as an examination or an operation In each case our emotions distort the actual length of the elapsed time

Distortion of time order and direction —What is true for the subjective estimate of time intervals holds equally for the determination of the order and the direction of time Normally, we are quite aware of the sequence of events in our lives and are convinced that we do not distort it Our memories give us an account of the past, our immediate experiences of the present, and our plans and predictions anticipate the future Consciously, we know that we can no longer change the past and that our conjectures concerning future events are at best probable

But it is also a well known psychological fact that past and future are often confused due to inattention, forgetfulness, and strong wishes or that the order of past events is not accurately recalled For instance, it may suddenly occur to us that we have promised to mail a letter, and we start frantically to look for it in order to take it to the post office, until we remember that we have mailed it last night The anticipated event is actually a past event Or we may be convinced that we have fed the cat right after breakfast, whereas she reminds us quite articulately that we have never done so The event which we "remember" never happened.

Cross-examination in court often reveals that memory confuses the actual order of happenings which can be established on the basis of more objective clues In dreams, events are juggled freely, unencumbered by logic or causality Psychoanalysts and psychopathologists know of many cases in which fantasy and reality are no longer distinguished, where the order of events is rearranged and even the direction of time is reversed in the patient's mind (Eckstein, 1954) The psychoanalytic concept of regression, however, is a metaphor characterizing types of behavior, not the opposite time direction

Errors in the determination of the objective sequence of events are due not merely to faulty memory and unconscious distortions because of conflicts but also to a faulty registering of the order of events by our senses The magician knows this fact and frequently avails himself of a sleight of hand A sound signal and a light signal may have been transmitted simultaneously, but, because of the higher velocity of light, we receive the light signal before the sound signal A naive inference may lead to a false conclusion concerning their times of departure

Distinction between Subjective and Objective Properties of Time

THEORETICAL REASONS

The foregoing considerations show that we must distinguish between the subjective experience of time in all its ramifications—

be it the determination of time intervals, the order of events in time, or the direction of time—and the objective physical properties of time The study of subjective experiences of time belongs mainly to psychology, whereas the ascertainment of the objective properties of time is the task of physics Although the present paper deals mainly with the objective properties of time, it does not disregard human beings, since the laws of physics apply to living organisms as well as to inorganic things We are interested in these physical laws because they help us to understand the world around us and the way we ourselves function as parts of nature The goal of philosophy of science is *to explicate these laws and the concepts pertaining to them*

PRACTICAL REASONS

The distinction between subjective and objective time not only serves a theoretical aim but is indispensable for practical reasons We simply cannot rely on our personal variable time estimates but need objective criteria for many purposes in everyday life and science

Let us illustrate these purposes by a few examples We want to standardize the work week forty hours must mean the same thing in California as in New York We need a standard time to catch a train or an airplane We are planning an international conference and must be sure that the date on our invitations to the participants means the same to all of them We are interested in comparing the average time it takes two different age groups to solve a problem We want to keep accurate records of historical happenings We want to ascertain the sequence of events leading up to a crime In all of these cases we cannot rely on subjective attitudes or perceptions

The Objective Properties of Time

There are three objective properties of time which will be analyzed in the following sections Until this point we have discussed various aspects and problems of time in an informal manner In the following sections the analysis will be taken up systematically

TIME METRIC

The metric properties of time concern the measurement of time, that is, the determination of the length of time intervals and their comparison In this connection many questions arise, for instance What kinds of definitions are involved in this issue? How should we choose a unit of time? Can we assume that time flows uniformly?

TIME ORDER

A further property of time is its order Logically, we can conceive of various order relations linear, circular, spiral, etc What type of order do the events in our physical world exhibit? Can we determine a univocal between relation with respect to these events, that is, are all physical events determinate as to their time order? Is time order reducible to a more elementary relation?

TIME DIRECTION

Finally we are interested in the direction of time How can we distinguish between earlier and later, between past and future? Are there physical processes which help us in this respect? Is it true that time goes in one direction only?

II Metric Properties of Time

The Notion of Measurement in General

THE ROLE OF CLOCKS IN TIME MEASUREMENT

We are interested in three objective properties of time the metric of time, the order of time, and the direction of time In this section we shall assume that there are methods by means of which we can determine the objective temporal order of events [illegible]

future We are concerned only with the

problem of determining how long a certain process lasts How do we find out whether we have waited for three minutes or three hours for news of a friend who is undergoing an operation? The answer seems to be very simple, instead of relying on our subjective sense of time, we consult a clock But this answer raises immediately a new question, namely How do we know that our clock is accurate? In fact, we might ask the even more fundamental question What is a clock?

DEFINITION OF THE UNIT OF MEASUREMENT

Requirement of a standard unit —In order to find the answers to the above questions, let us consider for a moment the factors involved in any process of measurement It is sometimes said that measuring is nothing but a process of counting When we measure the length of a room, we count the number of sections, each one yard long, that we mark off on the floor along one of the walls of the room When we measure the time needed to fly from San Francisco to New York, we count the number of times the minute hand on a watch completes a full sweep We see that we must decide what to count before we can make a measurement The result of a measurement is expressed by saying "so-and so many units " When we meet a friend and ask him, "How long have you waited for me?" he does not reply "Three " If he replied "Three," we would say immediately, ' Three seconds, three minutes, three hours, or ?" Measurement presupposes that a unit of measurement has been defined

Nominal definitions —How are we to define a unit of measurement? A definition usually asserts that two expressions in our language have the same meaning For example, "one minute" means the same as "sixty seconds," and a brother is defined as a male sibling Such definitions, sometimes called *nominal definitions*, may be used to introduce an abbreviation for a longer expression For instance, mathematicians introduce the symbol a^3 as an abbreviation for the expression $a \cdot a \cdot a$ At other times we may offer a nominal definition in reply to the question "What do you mean?" We give the meaning of the unfamiliar expression in terms that are already familiar to our interrogator Sometimes we may have to give a long chain of definitions before the other person understands what we mean

Ostensive definitions —But the chain of nominal definitions must come to an end Eventually, we arrive at terms for which we cannot give a nominal definition in our language without using terms that have occurred earlier in the chain If our interrogator is unfamiliar even with these primitive terms, we must resort to *ostensive definitions*, we point to the objects designated by the primitive terms Children learn their first words in this manner, they are told, "This is a house", "That is a chair", etc Every chain of nominal definitions is built upon a basis of primitive terms that are defined ostensively

Coordinative definitions —Terms that require an ostensive definition occur not only in the language of everyday life but also in the theoretical language of the physicist Since the physicist wants to use his theoretical language to describe the world, he must coordinate his concepts to physical objects or their properties In general, the coordination is not arbitrary We demand that any given concept be coordinated to exactly one thing, or one property of things, or one relation between things, in brief, the coordination must be unique But the concepts of physics are interrelated, as soon as some of the concepts are coordinated to the things in the physical world, we are restricted in our choice of further coordinations For example, if a centimeter is defined as the hundredth part of a meter and the concept *one meter* has been coordinated to a certain platinum bar in a vault at Sèvres, the object coordinated to the concept *one centimeter* must be chosen carefully When this object is laid end to end one hundred times, the meter bar must be exactly covered by it

However, our very first coordinations are just as arbitrary as are nominal definitions For this reason, we speak of *coordinative definitions* The fundamental units of measure-

ment are introduced by coordinative definitions Although certain practical considerations suggest that we choose as our standard —the object coordinated to the concept of unit of measurement—something that is reproducible, relatively indestructible, easily recognizable, etc, a coordinative definition is neither true nor false, it is merely more or less convenient

Coordinative Definitions of the Time Metric

THE UNIT OF TIME

We may now ask what kinds of entities are coordinated to the unit of time We can recognize the flow of time only because we observe change, the unit of time will be defined by coordinating it to a certain physical process The time elapsed from the beginning of the process to its completion is defined as one unit of time But the standard, we said, should be easily recognizable, thus we shall choose a process for which we can say definitely when it begins and when it ends We demanded, in addition, that the standard should be reproducible There are certain physical systems in which a process repeats itself continuously, namely, periodic systems A periodic system is a physical system that returns again and again to the same condition A pendulum swinging back and forth between two points traverses always the same path, it is therefore a periodic system

The rotating earth, too, is a periodic system, every day it turns exactly the same spot on its surface toward the sun

Any periodic system may be used as a clock, we may choose one such clock as our standard and coordinatively define the unit of time as the time required for one period of the system In fact, the unit of time used in physics is the mean solar day, the average time required for one complete revolution of the earth relative to the sun The concept *unit of time* is thus coordinated to a certain physical process In practice we use more manageable units of time, but for the latter we give nominal definitions Usually the physicist measures time in seconds, but he does not give an independent coordinative definition for this concept, he gives a nominal definition one second $=_{Df}$ one 86,400th part of the mean solar day

THE UNIFORMITY OF TIME

Uniformity of time and the laws of physics —Suppose that we have chosen a swinging pendulum as our standard clock How do we know that it requires equal times to run through successive periods? We cannot take one of the time intervals and lay it beside another to compare them, as we would do in the case of two measuring rods As a matter of fact, our pendulum will keep perfect time only if we keep it in the same position If we move it to a different place on the surface of the earth, where the gravitational attraction is slightly different, it will slow down or speed up Or let us consider the rotating earth The physicist does not take the solar day as his unit of time but the *mean* solar day, he knows that he must apply certain corrections because the earth does not merely rotate on its axis but also moves around the sun in an elliptical orbit He would be better off if he were to take as his unit the sidereal day, the period required for one complete revolution of the earth relative to the fixed stars rather than relative to the sun But even these revolutions do not keep "perfect time", the earth is very gradually slowed down by the gravitational influence of the moon and the sun For most purposes these slight defects of the earth clock are immaterial, however, the question arises whether there is a better clock by reference to which we discover these inaccuracies of the earth clock

Perhaps we should ask, rather, how we happen to *know* that the earth clock is inaccurate The answer to this question is surprising We know that the earth clock must be inaccurate, because the laws of physics tell us so It seems advisable, therefore, to take as our standard clock a periodic system which, according to the laws of physics, will complete its periods in exactly equal times This suggestion seems promising until we

ask ourselves how we know that the laws of physics are true The laws of physics relevant to our problem are those laws that deal with the time rate of change of certain processes for example, the laws of Newtonian mechanics or in modern times, the laws of Einstein s theory of relativity In order to find out whether these laws are true, we must have a clock only by using a clock can we find out, for instance, whether a stationary pendulum completes its periods in equal times However, the clock which we would thus use to check the law concerning the pendulum is itself another periodic system, and we can know whether this clock keeps accurate time only by another appeal to the laws of physics

We are thus placed in the following uncomfortable position Whether a periodic system is a satisfactory clock, that is, whether it requires equal times for the completion of each period, can be discovered only by appealing to the laws of physics Whether the laws of physics are true can be determined only if we have a clock We are caught in a vicious circle

Coordinative definition of uniformity — The existence of this vicious circle indicates the need for another coordinative definition We can break this circle only by picking out a physical system of which we simply *say* that it requires equal times for its periods This statement constitutes a coordinative definition, we do not claim that it is true For, if we were to claim that the statement is true, we would be faced with the problem of confirming it But any attempt at confirmation would lead again to the vicious circle described above

In the present context we cannot discuss in detail the considerations on the basis of which the physicist chooses his coordinative definition of the concept of *equal time intervals* It turns out, however, that there exists a large class of periodic systems that run through their periods uniformly relative to one another The swinging pendulum, the rotating earth, the vibrating crystal, and the electron spinning around the nucleus of an atom belong to this class If we choose any one of these systems as our standard clock, we find that the other systems in the class will complete their periods in equal times Moreover, we find that the earth revolves around its axis at a uniform rate, unlike the pendulum which swings fastest at its lowest points and slows down to a stop as it approaches its highest points The uniform rate of revolution of the earth enables us to divide the mean solar day into 86,400 equal parts, the seconds, which the physicists use as their practical unit of time Finally, using the earth clock leads to laws of physics of a particularly simple form All these considerations influence the choice of the physicist when he proposes his coordinative definition of uniform time, but they do not force him to choose a particular definition

COORDINATIVE DEFINITION OF A ZERO POINT

We may mention briefly another coordinative definition required not for time measurement but for the dating of events In order to test the laws of mechanics, it is necessary only that we have a unit of time and a coordinative definition for equality of time intervals But when we date an event, whether this be the departure of a train or a historical event such as the signing of the Declaration of Independence, we want to have a standard method We need a zero point from which we begin to measure time The date, or *time coordinate*, of a given event, tells us how long before, or how long after, the zero point the event occurs Here again we need a coordinative definition For example, 12 00 Noon Greenwich Time is the time when the sun passes the zenith at Greenwich, A.D 400 is the year four hundred years after the beginning of the Christian Era

Methodological Considerations

SUMMARY

So far we have considered the problem of defining a time metric We have seen that we need three metric coordinative definitions the coordinative definition of a unit of time, the coordinative definition of the

equality of time intervals, and the coordinative definition of a zero point The last does not raise any serious problems its choice is restricted by no considerations except that of unique identifiability The physical irrelevance of the zero point is, however, a fact that we want to point out, on many other scales—for example, the temperature scale—the choice of the zero point will affect the simplicity of our laws

The definition of a unit of time is also quite uncomplicated, the size of the unit does not affect the simplicity of the laws of physics In this respect, too, the time scale differs from the temperature scale

Only when we inquired into the coordinative definition of equality of time intervals did we find that the choice of the coordinative definition would affect the simplicity of the laws of physics This dependence of the laws of physics on the coordinative definition of temporal congruence may account for the fact that the need for a coordinative definition at this point had been overlooked for a long time The definitional character of temporal congruence became evident only after the vicious circle described above was recognized

SIMPLICITY

Inductive simplicity—Before we discuss the non metric properties of time, we shall pause to examine the notion of simplicity Simplicity plays an important role in scientific discussions, it will be shown, however that two different concepts—inductive simplicity and descriptive simplicity—must be carefully distinguished

Let us suppose that a scientist has performed a series of measurements determining the variations in a variable y with respect to given changes in a variable x The average times required for the completion of an assigned task by members of different age groups may serve as an example The results of the measurement may then be represented by points on a coordinate system (see Fig 1) The scientist now wants to discover the law governing the relation between the two variables For this purpose he constructs a curve which passes through the plotted points Of the many curves which he might draw, the scientist will in general choose the simplest continuous curve that fits the points Such a curve or the mathematical equation corresponding to it, not only describes the observed measurements but predicts the results of future measurements as well The choice of the simplest curve is based on the assumption that this curve will lead to correct predictions concerning the interpolated values This assumption is based on an inductive inference, we speak therefore of *inductive simplicity* The infinitely many different curves that we

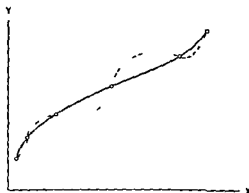


FIG 1—Inductive simplicity the simplest curve is in general most probable

might draw through the plotted points agree only in their description of the observed values they differ in their predictions concerning the unobserved values When we choose among this set of *non equivalent descriptions* the simplest one we appeal to the principle that the simplest description is the most probable one unless there is evidence to the contrary It is to be noted that the principle of inductive simplicity applies only to interpolated, not to extrapolated values

Descriptive simplicity—Whereas we appeal to the principle of inductive simplicity in order to choose among non equivalent descriptions, we base a choice between *equivalent descriptions* on considerations of *descriptive simplicity* The results of a measurement of length, for instance, may be stated either in terms of feet and inches or in terms of meters and centimeters The lat-

ter mode of description is preferred in the physical sciences because it is simpler in the sense that calculations within a decimal system are carried out with greater speed The two descriptions are, however, equivalent, the former is true if, and only if, the latter is true, and they lead to identical predictions Consequently, we cannot say that a descriptively simpler statement is more likely to be true, we can say only that it is more convenient Unlike inductive simplicity, descriptive simplicity does not involve a claim to truth

We said above that the customary coordinative definition of temporal congruence has the merit of leading to laws of physics that have a particularly simple form If a different definition were chosen, the laws of physics would have to be stated in a more complicated manner However, the new laws together with the new coordinative definition would be equivalent to the familiar laws together with the customary definition Since we are confronted by a set of equivalent descriptions, choosing the simpler description does not enable us to claim that the "true" description has been selected Only descriptive simplicity is involved in the choice of a coordinative definition

III Time Order

Distinction between Quantitative and Qualitative Properties of Time

TIME ORDER

We have distinguished the problem of constructing a time metric from the problems of time order and time direction The metric properties of time, also called *quantitative* properties, must be sharply distinguished from its *qualitative* properties In the previous section we have found coordinative definitions for all but one of the quantitative properties of time The remaining quantitative property, simultaneity, is better discussed after we have studied some of the qualitative properties of time

The qualitative, or topological, properties of time are in a sense more interesting than the quantitative properties Most philosophers have been concerned with the former, for they are the properties that give rise to our emotional reactions to time Before we study the distinction between time order and time direction, it may be well to recall these qualitative properties by formulating them in an informal manner We may then search for the physical significance of these statements

From childhood on we have been familiar with the graphical representation of time by a straight line Later we shall say that such a representation is adequate because the temporal order of events is of the same kind as the spatial order of the points on a line But even now we can see that this representation is appropriate We say of the straight line that it is divided into two parts by any chosen point on the line, similarly, we say that the present divides time into past and future We say of a straight line that it never returns to its starting point, similarly, we say that the past never comes back

TIME DIRECTION

In many respects time differs from a straight line We say that time flows from the past to the future, we do not say that the straight line goes from left to right For this reason we often prefer to represent time not by a simple straight line but by a straight line with an arrow tip on one end, that is, by a *directed* straight line

We said that a point on a straight line divides it into two parts, but these two parts are indistinguishable The present, which divides time into the past and the future, divides it into two distinguishable parts Some of the properties which distinguish the past from the future are expressed by the statements "We cannot change the past, but we can change the future", "We can have records of the past but not of the future", and 'The past is determined, the future is undetermined" (Reichenbach, 1956, pp 21 and 22) These statements are vague The philosophy of time is devoted to the task of clarifying their meaning, its problem is thus a problem of explication

Methodological Considerations

EXPLICATION

An explication must be distinguished from a definition When we introduce a new term into our language, we give a definition for it The definition states that the new term, the definiendum, has the same meaning as a certain combination of familiar terms, the definiens A definition is thus completely arbitrary, we may introduce new terms at will and define them as we please except for certain purely formal requirements

The need for an explication arises in a different situation In this case a term exists in our language which serves our everyday purposes more or less well but is not sufficiently exact for the theoretical purposes of science We therefore propose to replace the original vague concept, the *explicandum*, by a more precise one, the *explicatum* The new concept must satisfy certain conditions (Carnap, 1950, p 3) The explicatum must be sufficiently similar in meaning to the explicandum, so that in most contexts the explicatum can be used instead of the explicandum without changing the truth, or falsity, of our assertions However, the explicatum will not be synonymous with the explicandum, for the latter is vague, whereas the former is precise Exactness is a second requirement placed upon the explicatum Such exactness is achieved by laying down precise rules for the use of the new term Furthermore we demand that the explicatum be fruitful The new term should enable us to formulate and establish many laws that could not be stated by means of the original vague term For example, our explication of time order, time direction, past, future, etc , should enable us to reformulate the enigmatic statements about time mentioned above (p 50) in such a manner that we shall be able to understand them and to find out whether they are true or false To discover the precise concepts that will serve as explicata, we shall have to appeal both to logic and to physics

LOGICAL PROPERTIES OF RELATIONS

In the present section we are concerned only with the problems of time order But, before we can study these problems, it will be necessary to make precise the distinctions between order and direction, on the one hand, and between different types of order, on the other

When one speaks of relations, there is a tendency to think primarily of two term relations, for example, "father of," "older than," "is identical with " As a matter of fact, there are three-term relations, four term relations, etc The relation which holds among Smith, Brown, and a letter when Smith sends a letter to Brown is a three term relation

For the moment we shall restrict our considerations to two-term relations A relation [illegible]

with" is a symmetric relation, the relations 'father of' and "older than" are *asymmet-* [illegible]

[illegible]

A is the father of B, and B the father of C, then A is not the father of C

A relation R′ is the converse of the relation R just in case *R′* holds between B and A whenever *R* holds between A and B For example, *the relation "younger than" is the* converse of the relation "older than " Finally, we say of a relation that it is *connected* just in case it, or its converse, holds between any two members of the domain of discourse For instance, if we decide to speak only of human beings (the domain of discourse is the class of human beings), then the relation "older than" is not connected, there are many pairs of human beings such that neither is older than the other, that is, they are born at the same time But we might introduce instead the relation "older than or just as old as " This relation is connected, any two people A and B are so re-

lated, since either A is older than B, or B is older than A or A is just as old as B

LOGICAL CHARACTERIZATION OF ORDER AND DIRECTION

Open versus closed order—This brief digression into logic has prepared the ground for the distinctions between different kinds of order and between order and direction

It turns out that the order of an assembly of entities is completely determined if the *between relation* which holds for these entities is specified In order to illustrate different types of order, we shall compare the order of the points on a line with that of the points on a closed curve, say, a circle

Usually the between relation is regarded as a three-term relation, we say, "the point

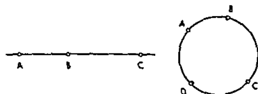


FIG 2—The points on a line exhibit an open order those on a circle a closed order

B lies between the points *A* and *C*," which we shall abbreviate by writing *ABC* However, in order to characterize the order of the points on a circle, we need a four term relation, we shall write *ABCD* in order to indicate that both *B* and *C* are between *A* and *D* and that *B* is between *A* and *C* and *C* between *B* and *D*

Let us now study the properties of the between relations that hold for points *A*, *B*, and *C* on a straight line and for the points *A'*, *B'*, *C'*, and *D* on a circle (see Fig 2)

We shall first consider the straight line We see immediately that, if *ABC*, then *CBA*, in other words, that the between relation is symmetrical in its end points The same is true of the between relation that holds for the points on a circle, that is, if *A'B'C'D'*, then also *DC'B'A'* However, further investigation reveals a characteristic difference On the open line, we find that, if *ABC*, then it is not the case that *BCA* On the circle, by contrast, we see that, if *A'B'C'D'*, then it is also true that *B'C'D'A'*

Following Grünbaum (in press), we shall call the relation that holds for the points on an open curve *o betweenness* and the relation that holds for the points on an (undirected) closed curve *separation closure* (or c betweenness) Analogously, the order characterized by o-betweenness will be called *open order*, that characterized by separation closure, *closed order*

We may now replace our earlier statement that the past never comes back by the more precise statement The temporal order of events is an open order However, we must still find an explication for the notion of temporal order

Extrinsic versus intrinsic direction—Before we turn to the problem of explicating the notion of temporal order, the distinction between order and direction must be explained Strictly speaking there are two distinctions namely, the distinction between order and direction, on the one hand, and the distinction between *extrinsic* direction and *intrinsic* direction on the other (Grunbaum, in press)

We need to know only the type of between relation that holds for the entities in a given set (e g, the points on a curve) in order to discover whether we are dealing with a case of open order or closed order However, the between relation is not sufficient for the determination of direction Both the continuum of points on a straight line and the continuum of real numbers are ordered by the relation of o-betweenness But, when we want to speak of direction in addition to order, we must appeal to an asymmetric, transitive, connected, two-term relation (p 51) A direction is assigned to the points on the straight line by means of the relation "to the left of" and to the real numbers by means of the relation "smaller than"

Whenever we have a set of entities that exhibit an open order, it is possible to assign a direction by means of a two-term relation *R*, which is asymmetric, transitive, and connected We merely choose arbitrarily two of

[illegible] numbers in the [illegible] the [illegible] For example, we choose the two points [illegible] and B [illegible] we choose the two real numbers —2 and —3 [illegible] —3 is smaller than —2 [illegible] even when we wish to define [illegible] we must appeal to an outside reference point, [illegible] of the observer who looks at the line. The relation "to the left of" cannot be defined by reference to the properties of the points on the line alone. For this reason we say that the direction assigned to the line (or the distinction between the two directions, from left to right and from right to left) [illegible] extrinsic.

It is different when we turn to the real numbers. The relation [illegible] than [illegible] definable in terms of the properties of the real numbers themselves. It can be distinguished from its converse [illegible] larger than [illegible] without appeal to an outside reference point. For example, we may give the following coordinative definition: Every real number which is the square of another real number is larger than any real number which is not the square of another real number. Thus the continuum of real numbers has an *intrinsic* direction.

Temporal order and temporal direction.— Once we have given a coordinative definition for the *temporal between relation* we shall see that the order of events in time is an open order. That the order is open is an empirical fact, not a matter of definition. We may then pick out two events arbitrarily and call one *earlier than* the other. We shall see below that this choice is not completely arbitrary: the two events must be causally connected.

The problem of the direction of time, however, is the problem of finding a coordinative definition for the relation "earlier than." If we can find a coordinative definition that does not appeal to anything other than the laws of physics, we shall be able to say that time has an intrinsic direction; if we must appeal to other phenomena, say the subjective time sense of the observer, time will have only an extrinsic direction.

[illegible] the laws of physics.

[illegible] The [illegible] of the present section will be devoted to the problem of time order.

The Causal Theory of Time

RELATION OF TEMPORAL ORDER TO CAUSAL ORDER

Hume's explication of causality.— It is obvious to everyone that there is a close connection between temporal order and causal order, between temporal direction and causal direction. The causal theory of time makes use of this connection: it defines (coordinatively) time order as causal order and time direction as causal direction. Causal theories of time from the work of the philosopher Gottfried Wilhelm Leibniz (1646–1716) to the early work of Hans Reichenbach (*Philosophie der Raum-Zeit-Lehre* [1928]) have taken the cause-effect relation as a primitive relation; only recently have attempts been made to reduce this relation further, that is, to define it in terms of the laws of physics (Reichenbach, 1956).

The philosopher David Hume (1711–76) explicates the causal relation by proposing three criteria. In order for A to be the cause of B, each of the following conditions must be satisfied: A must precede B in time; A and B must be contiguous in space and time; and A must be constantly conjoined with B. Hume clearly does not propose a causal theory of time; rather he uses temporal succession as a criterion for causal succession. We may, however, appeal to his second and

third criteria in our construction of a causal theory of time These criteria embody, respectively, the principle of action by contact and the principle of the invariability (or law likeness) of the causal relation

Causal connection —It is indeed the lawlikeness of causal connection which suggests that we need not take the cause effect relation as primitive but may analyze it further by appealing to the laws of physics Hume's criterion of constant conjunction is a criterion not for the relation of cause to effect but merely for the weaker relation of causal connection We give the following definition An event A is *causally connected* with an event B if, and only if, either A is a cause of B, or B is a cause of A, or there is an event C such that C is a cause both of A and of B (Reichenbach, 1956, p 29)

Many laws of physics assert merely causal connection They tell us that one physical magnitude varies in a regular manner as another magnitude changes For example, Robert Boyle discovered in 1660 that at a definite temperature the density of a given perfect gas is proportional to its pressure Such a law does not describe a physical process, it does not assert that the change in density is the cause of the change in pressure or that the change in pressure is the cause of the change in density The law asserts merely that these two changes are causally connected

REVERSIBLE AND IRREVERSIBLE PROCESSES

If we want to find laws of physics that enable us to assign a temporal direction, or at least a temporal order, to events, we must look for laws that describe processes and thus contain a time variable Laws of the desired kind are found both in mechanics and in thermodynamics It turns out that the laws of mechanics enable us to define merely temporal order, only the laws of thermodynamics supply an intrinsic direction for time

This difference between the laws of mechanics and the laws of thermodynamics is best explained by pointing out that mechanical processes are *reversible*, whereas thermodynamical processes are *irreversible* (This last assertion requires certain modifications which will be given below, p 64)

Illustrations —The distinction between reversible and irreversible processes is easily visualized if we imagine a filmstrip reeled backward Some of the processes depicted on the film look perfectly normal to us A train running backward along a track is not an unusual phenomenon, the flight of a ball thrown back and forth between two people looks just as "natural" when the movie is reeled backward as it does when the movie is reeled forward However, when we see a burning cigarette growing longer, or pieces of glass flying together to form a vase, we know that the movie is reeled backward, such processes "do not happen" These examples furnish an informal distinction between reversible and irreversible processes

Theoretical discussion —A physical process may be described by specifying the successive states of a physical system as a function of time We may say, for instance, "At the time t the train is in Los Angeles, and at the time $t + \Delta t$ it is in Chicago" Although the plus sign seems to indicate that the train went from Los Angeles to Chicago, it does not indicate that the process must have occurred in this direction The statement "At the time t the train is in Los Angeles, and at the time $t - \Delta t$ it is in Chicago" likewise describes a possible process The latter description would normally be regarded as a description of a run of the train from Chicago to Los Angeles, but it may also be regarded as a description in *the language of negative time* of a run from Los Angeles to Chicago We see that we have no grounds for the assumption that the plus sign indicates an objective direction of time

We may compare the above description with the description of the burning down of a cigarette At the time t the cigarette is 2 inches long, and at the time $t + \Delta t$ it is 1 inch long If we had described the process by saying, "At the time t the cigarette is 2 inches long, and at the time $t - \Delta t$ it is 1 inch long," we would not be inclined to say that this description is a description of

a cigarette growing longer Instead we would have insisted that the description was a description of a cigarette burning down but that the description was given in the language of negative time An irreversible process is a process that occurs in only one direction, from the description of an irreversible process we are able to infer whether the description has been given in *positive* time or in *negative* time A reversible process is a process which can occur in either direction, from its description we cannot infer whether the description is given in positive time or in negative time

Since mechanical processes are reversible processes, the laws of mechanics do not furnish an intrinsic direction of time It is, however, possible to define by means of mechanical (reversible) processes a causal between relation and then to determine whether the temporal order of events is open or closed

CAUSAL DEFINITION OF TIME ORDER

The between relation —Before we continue our investigation, we shall state the basic assertion of the causal theory of time and formulate precisely the problem before us The causal theory of time order proposes the following coordinative definition An event B is *temporally between* the events A and C just in case B is *causally between* A and C We are now faced with the problem of defining the relation of causal betweenness by appealing to the laws of physics and to processes described by these laws We shall see that the laws of mechanics enable us to lay down a coordinative definition for causal betweenness and, consequently, for temporal betweenness It will turn out that the mechanical processes observed by us indicate that the time order determined by this between relation is an open order The problems of time that arise in quantum physics will not be discussed in this paper

Let

prc

If

because of friction between it and the surface of the table, we may regard the velocity of the ball as constant The motion of the ball is then described by means of the two equations

$$x = v_x t \qquad (1a)$$

$$y = v_y t \,, \qquad (1b)$$

where v_x and v_y are the components of the velocity of the ball in the directions of the x and y coordinates, respectively Since we may think of the table top as covered by a two dimensional coordinate system, any pair of numbers (x,y) indicates a position of the ball on the table top

Clearly, the equations

$$x = -\,v_x t \qquad (2a)$$

$$y = -\,v_y t \qquad (2b)$$

also describe a mechanical process Thus we are unable to infer from either set of equations the direction in which the ball rolls

However, we are able to assert on the basis of equations (1) that the rolling ball describes a continuous path across the table If the ball is found in the southwest corner at time t_1 and in the northeast corner at time t_3, then it is found at various intermediate points at various times between t_1 and t_3 The principle of action by contact is satisfied by our equations, the ball does not jump from the southwest to the northeast corner without passing through a continuous chain of intermediate points Mechanical processes supply a temporal order because a moving object traverses a continuous path through space

Genidentity —The example of a movie strip will enable us to see how the laws of mechanics determine a causal order Let us imagine that a movie has been taken of a ball rolling across a table and that the film strip has been cut up into separate frames If we are now asked to reassemble the film strip, we say If the picture of a ball in the southwest corner and the picture of a ball in the northeast corner and the picture of a ball in the center of the table are pictures of the same ball, then the frame that shows the ball in the center must be between the frames that show it in the corners

The "if" clause in the above sentence in

dicates that we must know that the events to be ordered belong to the *same causal chain* before an appeal to the laws of physics enables us to assign a temporal order to them Since we restrict our considerations in this section to the macrocosm, we are able to single out sets of events all of which belong to one causal chain, namely, all those events that belong to the history of one macroscopic object Two events that belong to the history of the same object are called *genidentical* Any two genidentical events belong to the same causal chain but not all causal chains are chains of genidentical events

What are the additional requirements for genidentity? To be quite precise, we shall say that we are concerned here only with *material* genidentity (Reichenbach 1956 pp 225 ff) that is, with conditions that must be satisfied if we are to say of two events that they are states of the same macroscopic material object For example, if we were to meet Mr Smith again after thirty years, we might say, ' You have changed very much but we would maintain that he is the same person as before

We shall not lay down sufficient criteria for material genidentity, we shall simply take it as a fact that we can under certain favorable conditions determine that a string of events belongs to the history of the same object There are however, two necessary conditions that we should like to mention because we appeal to them when we attempt to establish the temporal order of events These two conditions are continuity of change and confirmability of change, respectively

The first condition may be exemplified as follows It is well known that when we see a person every day we do not notice how he slowly ages Aging is a continuous process except in very young persons we are hardly aware of the change But, when we meet someone again after many years, we are very much aware of the fact that he has changed When we nevertheless refer to this person as ' the same man I met in New York during the war," we indicate that we believe that the process of change, or aging, from then to now has been a continuous one Similarly, when we see a billiard ball rolling across a table, we see it in successive adjacent positions In this case we are aware of the change, but we are also aware of it as a continuous process If the ball suddenly disappeared at one place and reappeared simultaneously at a distant place, we would conclude that someone had performed a sleight of hand and that we were now seeing a different ball

This example is closely connected with the second condition If we observe that two billiard balls collide and bounce off each other in opposite directions, we do not say that they have interchanged positions at the moment of the collision for that would represent a discontinuous jump But we may not have watched the balls all the time, and, while we did not look someone may have interchanged them The process of interchanging the balls was of course a continuous process if we had watched we would not have had any difficulty in identifying the balls Even when we have not watched we are able to verify that an interchange of positions occurred because the balls will be identifiable by small scratches, by their colors, or by small differences in weight Only when such an identification is possible are we able to say, ' This is the ball that was earlier in a different place "

THE CAUSAL NET

Local comparability of time order — Mechanical processes enable us to assign a temporal order to genidentical events because they enable us to determine a causal *between relation Since mechanical proc*esses satisfy the principle of action by contact, a moving object passes through a continuous chain of positions Thus, to return to the example of the ball moving across a table (p 55), we know that the event of the ball's passing across the center of the table was temporally between its being in the southwest and northeast corners, respectively

Mechanical processes enable us to order not only the events in the history of one object but also events in the histories of dif

ferent objects, provided there is a causal connection between them

Figure 3 shows the collision of two billiard balls We may imagine that one of the balls describes the path *1–2–3*, while the other describes the path *4–5–6* In this case, we shall observe the practical coincidences *1–4*, *2–5*, and *3–6* We know that the coincidence *2–5* is causally between the coincidences *1–4* and *3–6*, but we do not know whether *1–4* is earlier or later than *2–5* It could also happen that we observe instead the practical coincidences *1–6*, *2–5*, and *3–4* However, it is possible to distinguish between these two sets of coincidences, that is we can find out by observation whether the second ball is in position *4* or in position *6* when the first ball is in position *1*

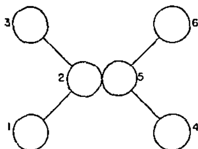


FIG 3 —Collision of two balls illustrating the local comparability of time order (Reichenbach 1956 p 34)

This fact illustrates the principle of the *local comparability of time order* This principle asserts "If two processes occur in spatiotemporal juxtaposition we regard a comparison of their time directions as possible" (Reichenbach, 1956, p 35) In other words, when we observe the changes in the *relative positions of two billiard balls and* assign a time direction to the events in the history of one of the balls, then we have thereby determined the time direction of the history of the other, our observations are incompatible with temporally counter directed causal chains We must note, however, that the time direction assigned to the causal chains is an extrinsic direction, the laws of mechanics and the mechanical observables do not provide an intrinsic direction of time

Because of the principle of the local comparability of time order, we are able to assign a causal, and thus a temporal, order to causally connected events even when the events are not genidentical In our example we are able to say that position *5* of the second ball is causally, and therefore temporally, between position *1* of the first ball and position *6* of the second ball In this manner we are able to construct a causal net, such as the net shown in Figure 4 As soon as we assign a direction to one of the causal chains, a direction will be assigned to all chains because of the principle of the local comparability of time order

Absence of closed causal chains —When we now examine the net as a whole, we discover that it has an open order This openness of the causal net is an empirical fact, not a matter of definition If we travel along *a causal chain, always following the direction* of the arrows, we shall never return to our starting point In other words, *there are no closed causal chains* Clearly, if we were to reverse the direction of all causal chains, the causal net would still be open, causal betweenness is thus found to be c betweenness (see p 52) The openness of the causal net, and consequently of time, is therefore an order property

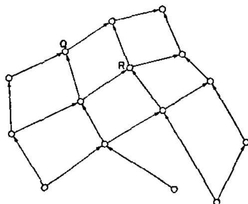


FIG 4 —A causal net *Q* and *R* indicate events for which no time order is determined (Reichenbach 1956 p 37)

Even if there were only reversible processes in our world, the open character of t

temporal order could be discovered How ever, the two directions of time would be indistinguishable The world in which we live is different We shall see in the next section that the existence of irreversible processes enables us to define temporal direction as well as temporal order in terms of the laws of physics alone The time direction of our world will then emerge as an intrinsic direction

The openness of the causal net is not logically necessary A world in which the causal between relation has the character of separation closure (or c betweenness), a world in which causal chains are closed, is not inconceivable As a matter of fact, we do not know that there are no closed causal chains in the universe as a whole, we know merely that there are no closed causal chains in that spatiotemporal part of the universe which is known to us

The statement, The past never comes back," which we mentioned above, has now been explicated Translated into precise terminology it reads, The order of the causal net is an open order " Although the precise formulation lacks the emotional appeal of the original statement, it has the merit of being a confirmable statement In fact, all human experience confirms the non existence of closed causal chains

Simultaneity at Distant Places

INDETERMINATENESS AS TO ORDER OF TIME

We are now able to return to a problem that we had to omit in our discussion of the time metric, namely, the problem of simul taneity

The openness of the causal net assures us that, if we take any two causal events A and B and call A earlier than B, we shall not find another causal chain between A and B on which B is earlier than A

Let us now imagine that we have a clock located at a certain space point P By means of our earlier coordinative definitions (Sec II) we are able to construct a time metric at P If we introduce coordinative defini tions for time direction and for the zero point from which we begin to count, then we are able to assign numerical values to the time coordinate for any event at P Are we able to extend the time metric of P to other points of the universe, say, to a point P'? If there exists a causal chain connecting an event at P, e_p, with an event at P', $e_{p'}$, we are able to say whether the event e_p is earlier or later than e_p Since we have assigned a direction to the causal chains at P, we are able to tell whether the chain goes from e_p to e_p or vice versa, in virtue of the principle of the local comparability of time order Let us suppose that e_p is the depar ture of a signal and $e_{p'}$ its arrival We are then able to say that e_p is later than e_p The possible values of the time coordinate of $e_{p'}$ are thus restricted by the condition $te_p > te_p$ (Let us repeat once more that we use "later," 'arrival," and 'departure" in a purely conventional sense We still restrict our considerations to reversible processes If we had decided on the opposite time direction for the events at P, then e_p would constitute the "arrival" of the signal and $e_{p'}$ its "departure," and the possible values of te_p would be restricted by the condition $te_{p'} < te_p$) But an infinity of values te_p is still open to us, we can assign a definite value to te_p only if we know the speed of our signal

There will also be pairs of events e_p and e_p of such a kind that there happens to be no causal connection between them In these cases we do not know their respective time order, consequently, we are unable to impose any restrictions on the possible values of the time coordinate of e_p The fact that we do not know the time order of e_p and e_p does not, of course, mean that these events are in fact not ordered in time There are, however, pairs of events e_p and e_p that are not only in fact not causally connected but for which a causal connection is physi cally impossible Since we have defined time order in terms of causal order, we have to say for such pairs of events that they are *indeterminate as to order of time* (Reichen bach, 1956, p 39)

THE RELATIVITY OF SIMULTANEITY

What does it mean to say that it is physically impossible for two events to be causally connected? The notion of physical possibility is difficult to define, but in the present context it is sufficient to say that an event is physically impossible if its occurrence would violate a law of nature (Reichenbach, 1954)

Even classical physics recognized the existence of space time points that could not

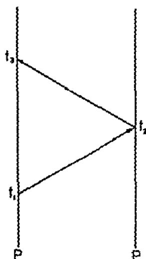


FIG 5—A light signal leaving point P at time t_1 arrives at point P' at time t_2, where it is reflected, it returns to point P at time t_3 The events of the interval from t_1 to t_3 at point P are excluded from causal interaction with the event occurring at point P' at time t_2 (Reichenbach, 1956 p 40)

be connected by causal chains Events constituting such space time points were regarded as simultaneous, and the same values were assigned to the time coordinates of such events Thus the fundamental meaning of simultaneity is simply indeterminateness as to order of time, that is, the absence of the possibility of causal connection

This definition of simultaneity is, however, not sufficient for the transfer of the time metric from one space point to another It would determine a unique event at the point P as simultaneous with a given event at the point P only if there were infinitely fast signals But one of the basic principles of the theory of relativity asserts that light is the fastest signal, there is no physical process of causal propagation that proceeds at a higher rate However, it has been known for centuries that the speed of light is finite

Let us now imagine two space points P and P' (see Fig 5) The vertical lines are the world lines of the points, that is, they indicate the time coordinates of the points At t_1 we send a light signal from P to P', it arrives at P' at t_2 and is reflected so that it returns to P at t_3 Since light is the fastest signal, no event at P between t_1 and t_3 can be causally connected with the event of the arrival of the light signal at P' Any signal sent from P in the interval between t_1 and t_3 would arrive at P' later than t_2, and no signal sent from P' at the time t_2 would arrive at P earlier than t_3

Thus all events at P in the interval between t_1 and t_3 are indeterminate as to time order relative to the event occurring at P' at the time t_2 all of them are simultaneous with the arrival of the light ray at P in the sense of the definition given above The relativity of simultaneity refers to this fact

EINSTEIN'S DEFINITION OF SIMULTANEITY

If we want to transfer the time metric of P to P', we must therefore introduce a further definition The definition, which is due to Einstein has the general form

$$t_2 = t_1 + \epsilon (t_3 - t_1)\,, \qquad 0 < \epsilon < 1 \qquad (3)$$

Before a value for ϵ is chosen, the definition indicates merely that t_2 is not earlier than t_1 or later than t_3 The "simplest" value is the value $\epsilon = 1/2$, but, since we deal with merely descriptive simplicity this value has no claim to being the "true value In the special theory of relativity the value $\epsilon = 1/2$ is chosen for two systems P and P' that are at rest relative to each other

We have indicated repeatedly that classical mechanics provides only an intrinsic

time order but not an intrinsic time direction Even when we appeal to the laws of the theory of relativity, we are not able to assign an intrinsic direction of time The laws of the theory of relativity, just as the laws of classical mechanics, *remain true if we* exchange the plus and minus signs before the time variable

With respect to the definition of simultaneity, this point is easily exemplified Suppose that we were to describe in the language of negative time the process of sending a light signal from P to P' and reflecting it there so that it returns to P We would then say that the signal left P at t_3 and returned to P at t_1 In this description t_2 would also be between t_1 and t_3, and none of the events at P in the interval between t_1 and t_3 would be causally connectable with the event of the arrival of the light ray at P' Moreover, the equation

$$-t_2 = -t_1 + \epsilon(-t_3 - [-t_1]) \quad 0 < \epsilon < 1 \quad (4)$$

results in a value for $-t_2$ which, as required, lies between $-t_3$ and $-t_1$

SUMMARY

Let us briefly summarize the conclusions arrived at in this section It is possible to define temporal order in terms of causal order An event B is temporally between the events A and C if, and only if, B is causally between A and C Events are causally connected if, and only if, there is a law of physics describing the relation between them Even if we restrict our considerations to *causal chains described by the laws of* mechanics, that is, to reversible processes, we are able to assign a causal order to the events on a given causal chain It is, however, impossible to distinguish between cause and effect, the laws of mechanics define only an order but not a direction of time

It is an empirical fact that the time order of events in our part of the universe is an open order Any two events that cannot be causally connected are indeterminate as to time order Since there are no infinitely fast means of causal propagation, there will be many events at any given space point P that are indeterminate as to time order relative to a given event at a point P' If we want to single out one of the events at P as *the event simultaneous with a given event at* P', we must *supplement the coordinative definitions* for a time metric studied in Section II by a definition of simultaneity

IV The Direction of Time

The Second Law of Thermodynamics

CAUSALITY AND THE DIRECTION OF TIME

The distinction between cause and effect — In the foregoing section we have seen that the time order of events corresponds to the order of points on a straight line, an order which is given by means of the relation *between* Yet, in the same way as a straight line does not have an intrinsic direction to the right or to the left, the ordered sequence of events does not indicate a direction toward the past or the future Classical mechanics does not furnish a direction of time because its processes are completely reversible

We have explained, furthermore, how time order can be reduced to the more elementary relationship of causal order and how the time order of classical mechanics, based on the between relation, became the source of the time order in the theory of relativity Einstein has shown that the relativity of simultaneity is one of the consequences of the reduction of time order to causal order *Yet just as the time variable t can be* replaced by the variable $-t$ in classical mechanics, the Lorentz transformations admit a reversal of the time order of those events which cannot be connected by causal chains The theory of relativity has therefore not made any contributions to the solution of the problem of time direction

In the following we shall investigate the question whether causality can, nevertheless, be employed to establish an intrinsic direction of time and whether its arrow can be said to point unequivocally in the direction of positive time

the concept of mere causal connection a criterion which will indicate the direction of the causal process

The two laws of thermodynamics.—We have mentioned above (p 54) that there exist two kinds of processes in nature, reversible and irreversible ones, and that the irreversible processes help us to distinguish between cause and effect Irreversible processes are familiar from everyday life when a cigarette is lighted, it grows shorter, never longer, when whiskey and soda are combined, the two liquids mix and do not separate again, when pottery is broken, it does not reassemble spontaneously We never question the fact that these irreversible processes go in one direction only

It is also well known that processes of temperature equalization are irreversible When an ice cube is thrown into a glass of water, the ice cube gradually dissolves, and the water becomes colder This result is not a consequence of the *first law of thermodynamics*, also called the *law of conservation of energy* It would be compatible with the first law if some of the heat contained in the ice cube were transmitted to the surrounding water, thus rendering it warmer than it was before, while the ice cube would become correspondingly colder The fact that such processes do not occur, that the flow of heat is unidirectional, is stated as an independent law, the *second law of thermodynamics* The two laws together govern the quantitative changes in thermal processes

We must distinguish between two quantities, *energy* and *entropy* According to the first law, energy remains constant during all changes in a closed system, according to the classical version of the second law, entropy remains constant during certain changes, increases during other changes, but never decreases during any change in a closed system Irreversible processes are characterized by an increase in entropy The second law of thermodynamics, therefore, furnishes the concept that must be added to the concept of causal connection, the concept of entropy will serve as a *criterion for the determination* of the direction of time

Entropy and the direction of time.—Before we discuss this concept in a more detailed manner, we should like to insert a word of caution It is easy to find examples which seem to contradict the second law of thermodynamics In every refrigerator the flow of heat proceeds in a direction opposite from that indicated above The interior of the refrigerator becomes cooler and the sur

energy is transformed into heat, and the increase in entropy produced in this process exceeds the decrease in entropy inside the refrigerator The second law of thermodynamics always refers to the total system involved and holds also for the refrigerator, even though in this instance the entropy of the subsystem decreases

Entropy can be regarded as measuring the degree of equalization reached by a closed system It is easy to understand what "degree of equalization" means when we think of the gradual heat exchange between two systems or of the tendency toward an equilibrium in mixing processes It was believed in the middle of the nineteenth century that ultimately all changes proceed in the direction of increasing compensation or higher entropy, not only in individual systems, but also in the universe as a whole Originally, positive time was therefore identified with the direction toward higher entropy

METHODOLOGICAL REMARKS

Probability.—Before we can study certain changes in the interpretation of the second law of thermodynamics, we shall have to explicate the notion of probability The concept of probability which is relevant to physics is exemplified by the following illustrations familiar from everyday life A life insurance company computes the premiums to be paid on a given policy on the basis of the probable number of years the insured

will live after he takes out the policy. A gambler chooses the odds with which he will bet on the outcome of a throw of a die according to the probability of the result on which he bets. Geneticists speak of the probability that a child of one blue-eyed and one brown eyed parent will have blue eyes.

In each of these cases the probability of the event in question is based on evidence which may be presented in the form of statistics. The statistics show that a certain percentage of the examined cases have exhibited the property in which we are interested. The probability statement itself is a prediction that in future cases the property will appear with the same frequency as before. The probability conception involved is, therefore, called the *frequency conception of probability* (Reichenbach, 1949, chap. iii, § 16).

A probability statement carefully formulated reads: If an event has the property A, then the probability that it will also have the property B equals p. For example, if a die is thrown (A), then the probability that it will show face 6 (B) equals 1/6. We shall introduce the following notation for probability statements:

$$P(A, B) = p \qquad (5)$$

We see from this notation that probability must be regarded as a relation. We cannot speak of the probability of face 6 but only of the probability that face 6 will come up if a die is thrown.

Probability is explicated as the limit of the relative frequency of the elements of the class B in the sequence of elements of the class A. The class B is called the attribute class, and the class A the reference class. It is easily seen that we must specify the reference class in all cases. The probability that a 40 year old man (reference class) will die within the next ten years (attribute class) is different from the probability that a 30-year old man will die within the next ten years. A life insurance company which fails to consider the reference class to which a new policyholder belongs will quickly go bankrupt.

We must, however, explain the meaning of the phrase "limit of the relative frequency." The relative frequency of B's in a finite sequence of A's is simply the number of entities that have both the property B and the property A divided by the number of entities that have the property A. Thus, if there have been 100 throws with a certain die, 15 of which resulted in the die falling with face 6 on top, the relative frequency of face 6 in this sequence of throws equals 15/100, or 3/20. If we now continue to throw the die, we may find that the relative frequency of face 6 in the sequence of 500 throws is 4/25, in the sequence of 1,000 throws, 3/16, etc. We notice that the relative frequency of face 6 approaches closer and closer 1/6 as the sequence becomes longer and longer. To say that the limit of the relative frequency, as the sequence becomes infinitely long, equals 1/6 is to say that the values of the relative frequency, as the number of elements in the sequence approaches infinity, approach more and more closely the value 1/6.

Since we never observe an infinite sequence a probability statement is always a prediction. We predict on the basis of the observed frequencies that the limit of the relative frequency will be close to the last observed frequency.

Causal versus statistical laws.—The laws of classical physics were always stated in the form "If   , then always   ." Whenever it was found that two kinds of events occurred together, or followed one upon the other, only in a certain percentage of cases, the physicists felt that they did not have sufficient knowledge—that they had omitted an important causal factor from their considerations. They felt that with sufficient experimentation and investigation they would always find laws that hold universally. We saw above that Hume considered constant conjunction as one of the necessary conditions of causal connection. We shall therefore refer to laws of nature of the form "If   , then always   " as *causal laws*.

In the second half of the nineteenth century a new conception of laws of nature appeared. The Viennese physicist Boltzmann pointed out that the second law of thermo

dynamics in its original formulation—in a closed system entropy never goes down—cannot be maintained and that it must be reformulated as a statistical law We can say only that it is *highly improbable* that entropy will decrease in a closed system We shall see below the reasons that led him to this conclusion

Although *statistical laws*, laws of the form "If , then in such a percentage of cases ," were accepted in physics after Boltzmann's discovery, the belief persisted that all statistical laws were based upon, and could be explained by an appeal to, causal laws Only the twentieth century development of quantum physics led many physicists to abandon the belief that all physical processes are ultimately explainable by means of causal laws

For our purposes, however, the question whether statistical laws are reducible to causal laws is irrelevant, only the distinction between causal laws and statistical laws is important We shall see that the statistical character of the second law of thermodynamics complicates the definition of the direction of time

THE STATISTICAL INTERPRETATION OF THE SECOND LAW OF THERMODYNAMICS

The statistical conception of entropy—We shall now consider the reasons which led Boltzmann to his reinterpretation of the second law of thermodynamics The perceptual quality of heat, or the quantitative degree of temperature, is reducible to the motions of the individual molecules constituting a system Temperature is therefore a function of the average speed of the molecules Temperature changes because individual molecules of different velocities collide and exchange their speeds In the majority of cases, the faster molecule will transmit part of its speed to the slower one, not vice versa The melting of the ice cube and the cooling of the surrounding water must be interpreted as a statistical compensation of differences in molecular speed The large number of particles involved lends a high degree of probability to the law of the increase of entropy, but its statistical character makes it plain that exceptions cannot be excluded We cannot completely discount the possibility, for instance, that by pure chance all the oxygen molecules of the air in our room will at some time be located on one side and all the nitrogen molecules on the other

Entropy increase is a transformation of improbable, ordered arrangements of molecules into more probable, unordered ones We shall see that the direction of time is closely connected with this statistical trend Because of the statistical nature of the second law of thermodynamics, our previous question, whether the *causal* theory of time lends itself to a definition of time direction, must be modified We have to ask whether the *statistical* conception of entropy, which permits exceptions to the second law of thermodynamics, will allow us to distinguish [illegible] [illegible] process going toward decreasing entropy can no longer be deemed impossible, only very improbable, we must not believe that these improbable processes would go in the opposite time direction Once we have assigned a direction to one causal chain of the net, this direction is assumed by the whole net, and positive time corresponds to the direction of the majority of thermodynamic changes We cannot maintain that a statistical definition of time direction leads to the consequence of a mere improbability that the past returns because such an event would close a causal chain The openness of the net is an order property and is perfectly compatible with a statistical conception of the direction of time

The reversibility objection—The difficulties that arose in physics at the time of Boltzmann concerned the question whether cases of increasing entropy are more probable than cases of decreasing entropy Physicists seemed to be faced with the following paradoxical situation On the one hand, the individual motions and collisons of the elementary particles are governed by the laws of classical mechanics and are their

versible, on the other hand, thermodynamic macroprocesses are irreversible The definition of the time direction seems to hinge upon the solution of the problem of how to reconcile the reversibility of microprocesses with the irreversibility of macroprocesses

Let us first become a littler clearer about the significance of the reversibility of mechanical processes In the kinetic theory of gases the probability that a molecule has a given velocity is assumed to be independent of the sign of the velocity Consequently, the reversed velocity has the same probability as the original one We must not expect, of course, that the molecules spontaneously and simultaneously reverse their velocities However, a state of the gas in which all the velocities of the molecules are reversed that is, a state in which they travel with the same speeds as originally but in opposite directions, is as probable as the original state and may occur in the course of time due to the continual exchange of velocities

In order to make this result more intuitive, we shall translate it into macrophysics Imagine a deck of cards in which all the red ones have been arranged on top of the black ones When we shuffle the cards, the original order will gradually be replaced by a random arrangement Nevertheless, if the deck is shuffled long enough, the original order of the cards will eventually reoccur because the probability of such a state is larger than zero, since all arrangements of the cards are assumed to be equiprobable

The deck of cards is a macroscopic analogue to a container holding two different gases which are separated by a wall As soon as the partition is removed, a mixing process begins in which the individual molecules correspond to the individual cards The probability metric assumed for this process permits an eventual return to the original ordered state in which the two gases were separated The *reversibility objection*, first raised by Loschmidt in 1876, maintains that sorting processes must be just as frequent as mixing processes

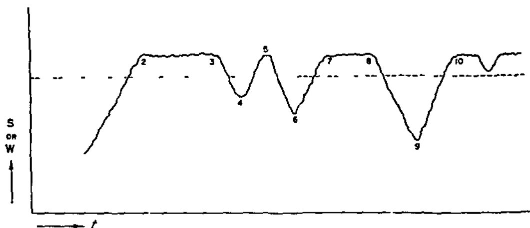


FIG 6 —The entropy curve of a closed system (Reichenbach 1956 p 111)

The symmetry between past and future in isolated systems —Figure 6 is a graphical representation of the fluctuations in the entropy S or the probability W of the various states during the history of a closed system consisting of two gases The curve beginning at point *1* represents the changes of the entropy after the partition separating the two gases has been removed The entropy rises until at point *2* an approximate equilibrium is reached This state will prevail for a relatively long time, yet intermittent fluctuations will give to the curve the irregular shape shown in the diagram When we study the diagram, we discover that every upgrade of the curve except the initial one is preceded by a downgrade Since one upgrade hard

ly makes a difference with respect to the relative frequency of both types of grades in an infinitely long sequence, we can neglect the first upgrade We arrive at the result that an infinitely long curve will have as many upgrades as downgrades or as many changes in the direction toward higher entropy as in the direction toward lower entropy We see that an analysis of the statistical nature of the second law of thermodynamics reveals the symmetry existing between the occurrences of upgrades and downgrades In an isolated system past and future are structurally indistinguishable, therefore, it cannot provide an intrinsic direction of time

The universe as an isolated system —We have derived the foregoing result from considerations concerning relatively small isolated systems But among the isolated systems there is one which is of special interest to us, namely, the universe Since astronomers have not yet settled the question whether the universe is finite or infinite, we shall consider the problem of the time direction for the universe as a whole first on the assumption that it is finite and then on the assumption that it is infinite

If we assume that the universe is finite and if we give, in addition, a definition of simultaneity (see p 59), we can speak of a momentary state of the universe at a certain time *t* or its *cross section* through the four dimensional space-time manifold If our description is given to the exactness of a micro state we can make a statement not only about the microprobability but also about the macroprobability, or entropy, of the universe at a certain instant because every microstate determines a corresponding macrostate Under these specifications Figure 6 represents not only the history of an isolated gas system but also that of the universe as a whole If we add the condition that time is infinite in the direction of the future as well as of the past, we must continue the curve in Figure 6 to the left of point *1* in the irregular shape of upgrades and downgrades similar to the curve drawn in the diagram For a finite universe we come to the same result as for an isolated gas system we see that there exists merely an alternation between upgrades and downgrades in a symmetrical fashion, and we cannot detect a criterion that would enable us to assign an intrinsic direction to the curve

In an infinite universe the probability of its states would be indefinable, and the concept of entropy is therefore inapplicable in this case For this reason we must restrict ourselves to an investigation concerning a finite universe

The Statistical Definition of the Direction of Time

THE RELATIONS BETWEEN TIME AND ENTROPY

The inference from time to entropy —Returning to Figure 6, we can ask the following two questions (Reichenbach, 1956, p 114) Can we draw an inference from time to entropy? Can we draw an inference from entropy to time?

The first question can be reformulated in the following way If the time direction and an observation of a low entropy state *A* of the system is given, can we say what the value of the entropy of a *later* state *B* of the system will be? If we let *A* be the class of points lying at the intersection of the dotted line with the curve in Figure 6, and if we choose a time interval between *A* and *B* that is not too small and keep it constant, it is more probable that the entropy of state *B* is higher than the entropy of state *A* rather than that the entropy of state *B* is lower than the entropy of state *A*

Yet, looking at Figure 6, we discover that we can draw the same conclusion if state *B* *precedes* state *A* in time For a constant time interval between *A* and *B* it is more probable in this case, too, that the entropy of state *B* is higher than the entropy of state *A* rather than that the entropy of state *B* is lower than the entropy of state *A* We see

presses the symmetry of the time direction for the entropy curve which we have stated in another form (p 63) Because of this sym

metry we realize that a premise concerning the time direction of the entropy curve is irrelevant for the inference from time to entropy Our result merely states an order property, namely, that upgrades and downgrades alternate and that upper levels are longer and more frequent than lower levels The inference does not furnish a distinction between past and future

The inference from entropy to time—Let us now turn to the second question, the inference from entropy to time This question can be reformulated in the following way If we observe two states A and B of a system and find that the entropy of state A is lower than the entropy of state B, can we determine which of the two states is the earlier one? We see immediately that it follows from the symmetry of the inference from time to entropy that it is impossible to decide whether state A is earlier than state B, or vice versa It is just as probable that a high entropy state precedes as that it succeeds a low entropy state

The result is striking the reversibility objection which we explained with reference to the velocities of individual particles in the microcosm remains in force with respect to macrophenomena The entropy curve of an isolated system does not enable us to draw a probability inference concerning the time direction of such systems

TIME ENSEMBLE AND SPACE ENSEMBLE

Time ensemble—If we do not want to capitulate before the paradox of the reversibility of elementary processes and the obvious irreversibility of macroprocesses, we must evidently revise our method Our experiences simply contradict the result that we have so far obtained For example, when we are confronted with two pictures of the same cigarette, one showing it when taken out of the package, the other when half-smoked, we do not want to give up our common sense belief that the second picture corresponds to a later state of the cigarette Why are we so convinced of this fact?

In order to answer this question, we have to recall the interpretation of the concept of probability given above (pp 61–62) The point that we should like to make here is that difficulties and differences concerning the application of the concept of probability are often resolved if the differences between the kinds of sequences to which the concept is applied are made explicit

We spoke of the probability of various states of the universe This probability, which concerns an entropy curve like that in Figure 6, refers to the history of *one* isolated system The sequence of the various states ordered in terms of the curve constitutes a *time ensemble*

Space ensemble—In contrast, our inference from the two different states of the cigarette, shown on two pictures, to the direction of time is not based on the history of a single cigarette In this case, the probability does not refer to only one sequence, the history of a single cigarette does not provide enough instances of change that would permit us to establish a relative frequency of different kinds of states Usually, we light a cigarette only once and smoke it to the end When we count the frequencies of different kinds of states of cigarettes, we take account of the histories of many cigarettes In this instance, we no longer refer to the sequence of states of one isolated system but to a *class of systems* Such a collection of similar systems is a *space ensemble* We have now made an important step forward It turns out that the probability which we employ for the purpose of inferring a direction of time refers to a space ensemble, not to a time ensemble

THE HYPOTHESIS OF THE BRANCH STRUCTURE

Interaction—Let us be quite practical in our approach and simply ask how we actually arrive at conclusions concerning the direction of time Suppose we are informed by one observer that he saw a container in which two gases were quite well separated, although no wall existed between them, and by another person that he saw the gases well mixed In this case, we shall unhesitatingly

call the second observation the later one, even though we have just learned that, according to the analysis of the time ensemble represented by Figure 6, the second state could just as well have been the earlier one It would not occur to us to maintain that the well ordered first state constitutes the result of chance fluctuations in a closed system, we would immediately assume that the gases had originally been separated by a partition which was subsequently removed We conclude that the improbable state is the outcome of an *interaction* between the system and its environment Our inference goes beyond the observation of one system and is therefore no longer covered by Figure 6

It is a familiar experience that through natural or artificial interaction or intervention many improbable well-ordered subsystems originate which, during their relative isolation from the larger system, gradually revert to more probable unordered states For instance, we pour cream into our coffee and create a subsystem that gradually develops from a low entropy to a high entropy state We do not believe, and it is not the case, that an initial improbable state such as the one just discussed is due to the chance development of an isolated system toward lower entropy, it is the result of a previous interaction of the system with a larger system whose entropy is on an upgrade We can regard the systems starting with a low entropy state and progressing toward higher entropy states as branches growing from a more comprehensive system The probability by means of which we infer a time direction then refers to such a *branch system* (Reichenbach 1956 pp 118 ff) which constitutes a space ensemble, for this purpose we do not count frequencies in a time ensemble

The probability inference —The inference referring to a space ensemble can be formalized The calculus of probability offers methods of treating both kinds of probability The situation which we described can be represented by a *probability lattice* For the sake of simplicity we shall dissolve the history of each branch into discrete events succeeding one another at short time intervals Symbolizing the individual events by y, we write (Reichenbach, 1956, p 119)

$$\begin{array}{ll} y_{11}\, y_{12}\, y_{13}\, y_{14} & y_{1i} \\ y_{21}\, y_{22}\, y_{23}\, y_{24} & y_{2i} \\ & \\ y_{k1}\, y_{k2}\, y_{k3}\, y_{k4} & y_{ki} \end{array} \qquad (6)$$

Each horizontal row represents the world line of a branch system and thus a time ensemble The vertical columns, however, represent space ensembles Each element y_{k1} in a row exhibits a highly ordered state which in the succeeding elements gradually changes to disorder If the horizontal rows were continued indefinitely, reversals toward low entropy states would occur

If A is a state of low entropy and B a state of high entropy we can ask for the probability that A is followed by B But we must state clearly to what kind of sequences we are applying this probability, that is, we must indicate whether we count frequencies in the time ensemble or in the space ensemble

In the following formulas the superscripts denote the position of the event in the lattice the repeated superscripts outside the parentheses the direction in which the frequency is counted

For the time ensemble we can write

$$P\,(A^{ki}, B^{k\ \ i+m})^{i} \qquad (7)$$

This probability is very high if m is not too small

We can also ask for the probability that A is preceded by B at the position $i - m$ We write

$$P\,(A^{k}, B^{k\ \ i-m})^{i} \qquad (8)$$

It follows from the reversibility objection that

$$P\,(A^{ki}, B^{k\ \ i+m})^{i} = P\,(A^{ki}, B^{k\ \ i-m})^{i} \qquad (9)$$

This formula simply reiterates the fact that we cannot use probabilities referring to the *horizontal rows for a definition of the time direction*

Let us now turn to the space ensemble and ask for the probability that A is followed by B after m elements For this purpose we count frequencies in the vertical columns If A and B represent the same entropy states as before, we have

$$P(A^{k\,i}, B^{k\,i+m})^{k} = P(A^{ki}, B^{k\,i+m})^{i}, \qquad m > 0 \tag{10}$$

Equation (10) exhibits a special property of probability lattices *lattice invariance* It is an empirical assumption that lattices of this type accurately describe physical phenomena such as mixing processes in the widest sense They permit us to make an inference from the time ensemble to the space ensemble Thus a cross section through the world lines of many individual systems reflects the structure of the world line of one individual system

The asymmetry of the space ensemble—We shall now ask the crucial question whether the space ensemble shows the same symmetry concerning preceding and succeeding events that prevails in the time ensemble if the rows are sufficiently prolonged It can easily be seen that lattice invariance does not hold for probabilities concerning preceding events in the vertical columns If we count vertically in those columns which are *not* too far away from the beginning of the branches, we find that the probability of a low entropy state being followed by a high entropy state is definitely higher than the probability of the sam[illegible] state being pre[illegible] The [illegible] therefore not [illegible] space ensemble and equation (10) is false if $m < 0$

The solution to the paradox depends on the distinction between a *one system probability*, the horizontal probability of the lattice and a *many-system probability*, the probability applied to the vertical columns of the lattice The directional symmetry of the time ensemble is translated into a directional asymmetry of the space ensemble In the space ensemble we can draw a conclusion from entropy to time, and by means of the theory of the space ensemble we can answer the reversibility objection

The solution of the problem of the direction of time remains unchanged if we substitute for the assumption that all branches start with relatively low entropy states the more correct premise that the great majority of branches have this property

TIME DIRECTION BASED ON FINITE SYSTEMS

Consequences concerning finite rows and columns—So far we have treated only one upgrade of the entropy curve of the universe and branches of infinite length But we know from symmetry considerations that the upgrade of the main curve will gradually develop into a horizontal part signifying a state of equilibrium, which in turn will be followed by a downgrade, and that this shape will repeat itself at irregular intervals In addition we know that the subsystems do not remain isolated forever but will interact again with their environment For example, the subsystem of an ice cube in a glass of water will develop from a highly ordered state into a state of temperature equalization gradually, the temperature of the water will approach that of the surrounding air Under these circumstances we can no longer regard the glass of water as an isolated system

This situation is diagramed in Figure 7 In this case neither the rows nor the columns of the corresponding probability lattice are infinite But their length is sufficient for our purpose, even though the rows do not lend themselves to a counting of frequencies of entropy states that would demonstrate the symmetry between high and low ones This fact does not make any practical difference, since we do not live long enough to observe reversal processes The main curve, on the other hand, is infinite in length and realizes the horizontal probabilities

Time direction and the entropy curve of the universe—In the vertical columns the frequencies of entropy states can be counted, but the result differs from that derived for schema (6) Branches on the upgrade of the

main entropy curve start with low entropy states (points *1*, *3*, and *5* in Fig 7), branches on the downgrade of the entropy curve begin with high entropy states (points *7*, *9*, and *11* in Fig 7), provided we follow the main curve in one direction This pattern of alternating high and low entropy states is repeated in equal frequencies when we imagine the main curve prolonged toward the right We find that for the total entropy curve of the universe our definition of time direction does no longer hold

The sectional nature of time direction – It seems that we have to restrict ourselves to individual sections of the main curve and to

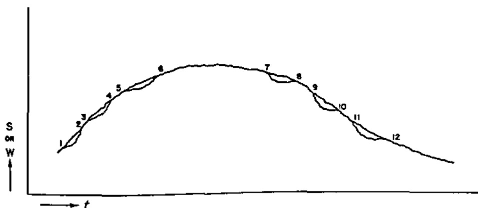


FIG 7 —An upgrade and a downgrade of the entropy curve of the universe Some isolated systems branch off and return to the main system (Reichenbach 1956 p 127)

modify our definition correspondingly Only with regard to these sections can we say that the direction of positive time is the direction in which most thermodynamic processes in isolated branch systems occur

This result has strange consequences If we assume that the section we are considering is an *upgrade* of the main entropy curve our statistics will always concern only the space ensemble of this section the observable frequencies will reflect the asymmetry in the sequences of high and low entropy states of the cross sections through the isolated systems and supply a definition of positive time

If we apply these considerations under the assumption that the main curve is a *downgrade* we come to the following results In this case the definition furnishes the opposite direction as the direction of positive time as is clearly illustrated by Figure 7 We must conclude, therefore, that we cannot speak meaningfully of an intrinsic direction of time as a whole Only certain sections have directions and these sections are counterdirected Time comes in threads, and our definition of an intrinsic time direction applies only to the separate sections, not to time as a whole

Although this result appears counterintuitive it does not lead to a logical contradiction Neither the order properties nor the direction properties of time can be determined by reason alone The sectional nature of the time direction is derived from an analysis of the entropy curve of the universe and constitutes an empirical result

If this result is correct, the counterdirected sections of the universe are separated by *long periods of relatively stable high entro* [illegible]

fined to rather short intermediate parts of the entropy curve and we shall never be able to observe a reversal of its direction Thus the assumption of alternating time directions would not contradict our experiences Perhaps we are living right now on a grade of the entropy curve that is 'really' going down Here we must stop for a mo

ment and ask whether it makes sense to say that the entropy "really" goes up or that the time direction is "really" positive According to Boltzmann, this problem is similar to the question whether we or our antipodes are "really" standing up

Consequence for time order —It is meaningful, however, to speak of time as being pieced together of counterdirected sections because for a definition of *time order* we do not have to resort to entropy In addition to the time in those sections which define an intrinsic direction of time, there exists a *supertime* in which events are ordered along the upgrades, the states of equilibrium, and the downgrades Neither time as a whole nor stable high entropy sections have an intrinsic direction, but time order can be maintained for both Since time as a whole has an open order, it is, of course, possible to *assign arbitrarily an extrinsic direction to* time as a whole (see pp 52–53) Let us suppose that the extrinsic direction assigned to time as a whole is that represented by the arrow in Figure 7 For the upgrade of the entropy curve, we find that, if the event *A* is earlier than the event *B* according to our definition of the intrinsic direction of time (the definition in terms of entropy increase), then *A* will also be earlier than *B* according to our definition of the extrinsic direction of time However, when we come to the downgrade of the entropy curve, the two definitions will no longer lead to the same result According to the definition of the extrinsic time direction, represented by the arrow, the point event *7* is earlier than the point event *8* According to the definition of the intrinsic direction of time in this section of the universe, the point event *7* is later than the point event *8* This surprising result need not disturb us Whether a statement of the form "*A* is earlier than *B*" is true or not can be decided only after a time direction has been defined, it may, therefore, be true with respect to one definition and false with respect to another Similarly, a statement of the form "*A* is simultaneous with *B*" may be true with respect to one definition of simultaneity and false with respect to another (p 59)

able states through their interaction with other systems, remain isolated for some time, and gradually develop toward more and more probable states The intrinsic direction of time is furnished through the direction of increasing entropy in the plurality of the branch systems

Extension of the Statistical Definition of Time Direction to the Macrocosm

MACROSTATISTICS

Macro-mixing processes —The foregoing statistical considerations can be extended from microprocesses, whose elements are molecules, to processes whose elements are macro objects such as playing cards or grains of sand We are interested in this extension because we should like to find out what assumptions are required for a macro statistical definition of the direction of time

When we shuffle a deck of cards, we can regard the result as a mixing process By analogy with a gas system, we can speak of the low macroprobability of an ordered arrangement of cards An ordered arrangement is characterized by a rule which is easily discernible, such as an arrangement of all the red cards on top of the black cards or an arrangement of the deck according to suits *Shuffling destroys the original order* and gradually produces unordered arrangements which have high macroprobabilities and hence high macroentropies Such a shuffling process is represented by the initial section of the entropy curve in Figure 6 If the shuffling is continued, the curve will remain on a high level and show only minor fluctuations It is very improbable that the

in this sense that the shuffling process has the properties of an irreversible process, al

though, of course, we could intervene and sort the cards, an intervention which is not possible in the microcosm

For microprocesses we assumed that an improbable state of a closed system is due to an interaction with the environment rather than to a chance configuration of molecular fluctuations We see that in the macrocosm similar relations hold If all the red cards are on top of the black cards, we assume an intervention and not a chance result of the act of shuffling

Records—One important difference between microprocesses and macroprocesses consists in the fact that the former have "built in" shuffling mechanisms supplied by the collisions of the molecules Macrostates either do not change by themselves from order to disorder and require deliberate human intervention for this purpose or their transition toward disorder proceeds so slowly that change remains imperceptible for a long time A random arrangement of cards, for example, is not the natural end product of a previously ordered arrangement, boulders transported by glaciers will resist destruction for a considerable time Macro order, because of its persistence, can be observed at leisure Macrostatistics present us with *records*, and records, in turn, help us to gain a deeper understanding of the relation between causal explanation and the direction of time

We should like to clarify this problem by the following illustration Let us imagine that we find clearly recognizable footprints in the sand, a "record," from which we infer that some time earlier a human being walked along the beach What interests us at the moment is the logical reconstruction of this inference

By means of simple rules we can distinguish between various macrostates of the sand which represent different arrangements of the grains Among these states there is one which is characterized by a relatively smooth surface, another one is patterned by footprints These different states do not have equal probabilities, because the wind exercises a selective influence upon them When changes occur solely as an effect of the action of the wind, a leveling of small elevations and a smoothing out of holes is much more probable than configurations in the form of distinct patterns, except perhaps for wavelike shapes A smooth surface would thus constitute an unordered state, whereas sand patterned by footprints would represent a highly ordered state How do we explain this order?

EXTENSION OF THE HYPOTHESIS OF BRANCH SYSTEMS TO THE MACROCOSM

Cause and effect—From our discussion of micro order we remember that we explain the improbable state of an isolated system in terms of a previous interaction of the system with its environment This explanation makes use of many system probabilities based on the assumption of branch systems We shall now extend this hypothesis to macrostatistics The footprints, which constitute an improbable state, record an interaction of the sand with the feet of a person This event signifies the beginning of a branch system which slowly runs its course from order to progressive disorder The wind gradually erases the pattern and smooths out the surface

We are now in a better position to explicate the meaning of "cause" and "effect" with the help of the concept of branch system We employ causal explanation when we are faced with improbable order states of isolated systems, the interaction of a subsystem with a larger system is the cause, the improbable order exhibited by the branch system is the effect

In ordinary language "cause" refers to the past and "effect" refers to the future This usage can be illustrated by many examples The orderly shape of a hedge is explained as the effect of a previous interaction between the gardener's shears and the bushes, the hole in the stocking is the effect of a nail sticking out of a chair, a heart surrounding initials on the bark of a tree is the effect of a previous interaction between a knife and the wood As soon as these systems have reached their thermodynamic equilibriums subsequent to the interaction,

not a human prerogative to reflect the flow of time What we feel to be the direction of time, the direction of *becoming*, is a relation between a registering instrument and its environment Man s brain functions like a registering instrument and is governed by the laws of information theory Like all other registering instruments, it defines the time direction in terms of increasing information It follows from the statistical isotropy of the universe that this relation is the same for all such instruments including the human brain

V Concepts of Age and Aging Applied to Inorganic and Organic Systems

Age

DEFINITION OF AGE IN TERMS OF WORLD LINES

In the following sections we shall presuppose all the results that have been derived in the previous sections of this chapter We shall take for granted that an adequate time metric can be defined that events are ordered along causal chains, and that the direction of positive time is identified with the direction of increasing entropy and increasing information

The concepts of age and aging are, of course, intimately connected with the passing of time If we were to attempt a definition of age ' applicable in general to any kind of system organic or inorganic, closed *or open, we seem to come closest to its meaning* in everyday language if we define it in terms of ' length of the world line of a system " Once a time direction has been assigned to one causal chain of the net of events, every world line has an arrow, and all arrows point in the same direction

Qualitatively speaking, we can say the longer the world line of a system, the older the system After a metric has been introduced and the ' birthday" of a system is known, we can make a quantitative statement about the age of the system In the course of time we may observe the system at regular intervals and find out whether the corresponding states of the system are relatively static or exhibit continuous change These observations will guide us in our decisions concerning the kind of changes we are willing to call ' aging" and what kind of states induce us to call the system ' old "

' Aging" and ' old" are relative terms Although two systems may have equally long world lines, we often characterize the one as young and the other as old A 14 year old dog and a 14 year old car are old, but a boy of 14 is young, and for a star 14 years would represent an infinitesimal part of its world line The concepts of aging and old are in most cases used relative to the total average life span of a system, and life spans vary in the organic as well as in the inorganic realm

INFERENCES CONCERNING AGE

There are many cases, however, where we are ignorant about the length of the world line of a system either up to the present because we do not know when it started or *in toto* because its life span exceeds possible human observation For example, the age of many persons whom we meet is unknown to us, and the astronomer has no exact data concerning the age of planets and stars Yet we may be able to infer from the present state of a system, or from an observation of the changes it undergoes, or from its relation to the environment how old it is

Not all systems permit us to make such an inference Mixing processes and thermodynamic processes which have reached an equilibrium lend themselves only to the minimum statement that the system must have existed at least as long as it took the system to develop from an ordered state to the observed unordered state But we can not ascertain from the observation of the equilibrium state how old the system is altogether, for the obvious reason that almost no macroscopic changes occur after the system has reached a high entropy state

THE INFERENCE FROM THE SPACE ENSEMBLE TO THE TIME ENSEMBLE

Isolated macroscopic branch systems, however, which preserve their improbable order for some time and thus function as records as well as systems undergoing observable changes, give us information about their age Ancient statues, stones with inscriptions, prehistoric tools, and fossils imbedded in the various geological strata can theoretically be dated They are instances of frozen' improbable order A striking example of observable changes indicating the age of a system are the rings added to the trunk of a tree during the years of its existence

The inference from a momentary state of a system to its age is again an inference from the space ensemble to the time ensemble Darwin used this method in order to establish the evolutionary sequence of the different species (Reichenbach, 1951, chap XII) After he had ordered the coexisting species systematically according to their degree of differentiation, he made the inference that this order represented at the same time their historical order of evolution, namely, their development from the amoeba to man His theory is supported by the discovery of fossils in different geological strata The more differentiated species have been found in the more recent geolog al form t n and th s

fossils with the temporal order of their deposition. In addition to these qualitative results, more exact quantitative statements concerning their relative age can be made on *the basis* of their proximity to the various geological layers whose age is known on other grounds

In our previous example the generalization that trees add one ring every year presupposes the observation of many trees and thus makes use of a many system probability Astronomers, too, make inferences from the space ensemble to the time ensemble for the purpose of estimating the age of stars They have observed the simultaneous existence of stars of different luminosities and have been able to construct a systematic order for them They have concluded that this order, extending from the red giant to the white dwarf, can be regarded as representing the historical order of the stages run through by the individual star Another example is the determination of the age of the earth which is based on a sort of geological clock Radioactive substances like uranium radium, and thorium are changing continuously They are decaying at well known rates and are finally transformed into lead The ratio of the amount of radioactive elements to the amount of lead existing on the earth at the present time gives the geologist the evidence for the calculation of the time needed to produce all the decay material from pure radioactive substances Of course, the half lives of the different radioactive elements had to be established before they could be used as time indicators

Distinction between "Age" and "Aging"

BIRTH AND DEATH IN RELATION TO AGING

The concept of age is more general than the concept of aging We can speak of the age of any system without applying the notion of aging If no changes are observable, or if we are ignorant of them, we talk of age, when we are aware of changes, we may or may not use the predicates 'aging" or old" There is a certain ambiguity connected with the word "old" The opposite of old' as a characterization of organic systems is young," *but with reference to in*organic systems the opposite of "old" is sometimes 'young" but frequently "new" We speak of old and young plants, animals, and people, also of old and young stars, of aged whiskey and young wine, but we speak of old and new clothes, old and new machines, old and new houses

We use the terms 'birth" and "death" where no aging process is going on, since in many cases things cease to exist not because

of continuous changes resulting in gradual deterioration but because of a sudden calamitous interaction with their environment Fatal accidents happen to living organisms, islands are suddenly "born" and just as suddenly disappear again in the ocean, telephones are "dead" because a storm has severed a wire The words "old" or "dead" are applied to volcanoes when we want to say that they are no longer active In this instance "dead" means that the volcanoes have reached a thermodynamic equilibrium state "Death" is used in a similar sense when the astronomer speaks of the heat death of the universe He refers to a possible future entropy state in which all thermodynamic processes going on in the stars have arrived at a state represented by the horizontal section in Figure 6

We have given some illustrations showing how the concepts of age and aging are applied to inorganic physical systems by analogy with biological systems Let us now have a closer look at this analogy because there exist some fundamental differences between the aging processes of these two kinds of systems

DIFFERENCES BETWEEN ORGANIC AND INORGANIC SYSTEMS

Living organisms, in contrast to some inorganic physical systems, are always open systems They are in constant interaction with their environment which provides their sustenance but which is also fraught with dangers that the organism has to ward off or to overcome Man for example, breathes the air and takes the food available in the external world, he repairs the injuries inflicted by the environment, resists harmful bacteria, and flees from outside attack All these mechanisms serve to preserve or restore the equilibrium or *homeostasis* of the body Here we can see an important difference between living organisms and non living physical systems the former have the faculty of self regulation All their functions can be characterized from this point of view In addition to self regulation, the processes of nourishment, elimination, and repair result in a continuous exchange of the original material of the body for new material Inorganic systems, however, have no self regulating mechanisms and retain their original material unless they are artificially repaired

SENESCENCE

There is a difference, therefore, between an old man and an old car "Senescence" is a term designating those processes in certain biological systems which lead to a failure of the self regulating mechanisms and diminish homeostasis with advancing age (Beck, 1957, pp 281 ff) The car was never endowed with self maintaining defense mechanisms against wear and tear

There seems to be no ultimate consensus at the present time whether senescence is the inevitable effect of hereditary traits, whether it is caused by traumata experienced by the organism, or what role both factors may play in this connection Apparently, no single factor can be named as an explanation of the different types of senescence that occur The subsequent chapters of this book will discuss in detail the facts that are known about the phenomenon of aging in living organisms

Since man is conscious of the changes in mind and body that accompany increasing age, he will inevitably react psychologically to the irretrievable passage of time We should like to close this section with an aphorism by Georg Christoph Lichtenberg expressing some thoughts about this fact The quotation will at the same time serve as a transition to the last section of this chapter, which deals with some emotionally inspired attitudes and theories about time contained in various metaphysically oriented philosophical systems

> When we are young we are scarcely conscious of living The feeling of health is only acquired by sickness It is when we jump up, or because [illegible]
>
> the recollection of the past remain, we should hardly be aware of the change For this reason

I believe that it is only in our eyes that animals grow old A squirrel that on its death day leads the life of an oyster is not unhappier than the oyster Man however, who lives in triplicate—in the past, in the present, and in the future—may be rendered unhappy by but one of the three being amiss Religion has even added a fourth—eternity [Alliston 1903, pp 43–44]

VI Time in Literature and Metaphysics

Time in Literature

THE STREAM OF CONSCIOUSNESS

At the beginning of this chapter we emphasized the difference existing between the objective properties of time and the manner in which time is frequently experienced subjectively We have shown that it is possible to account for the metric, the order, and the direction of time in physics in terms of causal relationships between events, and we have pointed out the role which definitions play in this theory

The sequence in which personal experiences are remembered, the subjective fusion and confusion of actual happenings in memory, is likewise accessible to causal explanation But psychological explanations refer to emotional associations and "the logic of the heart" rather than to the laws of mechanics and of thermodynamics In many instances dynamic psychological principles, such as repression, projection, displacement, and distortion, are at work Thus the same objective physical order of events, when experienced by different persons may correspond to many different subjective reconstructions

But not all experiences are remembered, many of them are forgotten As an instrument of unearthing forgotten experiences for the purpose of giving the patient a sense of continuity and a better foundation for self identity, psychoanalytic therapy employs the method of free association This device has been used in literature under the name of 'stream of consciousness' The stream of consciousness is familiar from introspection Although seemingly carrying on its surface unrelated fragments of thoughts, dreams, and fantasies, it may eventually lead a person back to the well of "remembrances of things past" If successfully integrated, this piecemeal way of narrating a story may in the end present the reader with the vivid portrait of an individual

TIME AND METAPHYSICS

Time and eternity—Through the ages, from Ecclesiastes to Joyce, from the Pre Socratics to existentialism, time has impressed and puzzled writers and philosophers For many time was an intense emotional experience, and their works show their attempts to cope with it It is not our task in this chapter to give a detailed account of time's emotional impact on human beings as it is mirrored in literature, philosophy, and religion We merely wish to pick out one conception of time which seems to defy a classification as either subjective experience or objective description

This interpretation of time, which emerges from some of the more speculative philosophical systems and is far removed from scientific analysis, is a kind of superstructure erected on the common sense foundation of experienced time, an interpretation that can only be called "metaphysical" or 'mystical' It has no analogue in science or in experience, even though it often comes in the guise of a logical argument trying to prove what some religions accept on faith

Among the Greek philosophers, Democritus, Pythagoras, Parmenides, Zeno, and Plato taught that true reality is *eternal* The word "eternal" has three meanings (1) it is a state of existence that has an endless duration, (2) it is a state of existence that is completely independent of temporal conditions, and (3) it is a state of existence that includes time but transcends it

Democritus—Democritus regards atoms as eternal in the first sense They have always been, and will always be, immutable, indestructible drawing endless world lines through the universe Modern physics has shattered this view even with regard to the

constituents of the atoms Democritus, who is a materialist, assumes that there is only one realm of existence

The second meaning of "eternal" is illustrated by the philosophy of Pythagoras Pythagoras was deeply impressed by the fact that mathematical truths are not in time but are eternal verities Since no physical object realizes exact mathematical proportions, since nothing is perfectly circular or perfectly square, mathematics seems to apply to ideal things And from timeless truth the step was made to timeless existence Reason alone has access to this perfect, supersensible, and timeless realm It is easy to understand how this view can lead to an almost religious veneration of reason as opposed to sense perception

Parmenides —Under the influence of this doctrine Parmenides taught that reality is eternal, unchangeable, and revealed to pure thought Happenings in time are illusions, as Zeno subsequently tried to show through the paradox of the flying arrow When time flow is regarded as an illusion, as in the philosophy of Parmenides and Zeno, there exists only one timeless reality

The third conception of eternity, however, splits reality into two different realms, a temporal imperfect one and a timeless one of perfection In this conception eternity includes time but transcends it Religious language mirrors this division in the familiar distinction between the here now and the hereafter, the vale of tears and eternal blessedness, the experiences of the finite human mind and those of the infinite mind of God

Plato —Plato's philosophy is an illustration of this metaphysical dualism According to Plato, the physical world with its ever changing phenomena is a copy of the static realm of essences or ideas The world of sense is a world of shadows and mere reflections, in heaven there are the true patterns of all physical things Time is an imperfect copy of eternity

When the father and creator saw the creature which he had made moving and living, the created image of the eternal gods he determined to make the copy still more like the original, and as this was eternal, he sought to make the universe eternal so far as might be possible Now the nature of the ideal being was everlasting, but to bestow this attribute in its fullness upon a creature was impossible Wherefore he resolved to have a moving image of eternity, and when he set in order the heaven, he made this image eternal but moving according to number, while eternity itself rests in unity, and this image we call time Time, then, was framed after the pattern of the eternal nature, that it might resemble this as far as possible, for the pattern exists from eternity [Jowett, 1953, II, 19]

The conception of an imperfect physical world governed by change leads Plato to a disparagement of empirical knowledge The physical world, the world of Becoming, is apprehended by the senses, and they give us only true opinion, whereas the rational world, the world of Being, is apprehended by intellectual vision, and this vision yields true knowledge

Kant —The metaphysical dualism in the form of two realms of existence was repeated in a less mystical manner by Kant in his distinction between the things of appearance and the things in themselves, the phenomena and the noumena According to Kant, all our knowledge refers only to the world of appearance, about the noumena we cannot know anything Time is merely a form of our intuition, the way in which we perceive change in the world of appearance, and it is not an attribute of the noumena which are timeless In modern terminology we would say that Kant gives a subjective interpretation to time—that he teaches the ideality of time which has its ground in the constitution of the human mind The noumena, however, exist *sub specie aeternitatis*

Although perhaps not mystical, Kant's reasons for denying the reality of time were probably religious He feels that, in spite of our ignorance concerning the things in themselves, pure practical reason will arrive at certain postulates about this realm which are indispensable for ethics Among these postulates we find immortality, that timeless existence which in Christian tradition provides salvation beyond the grave

The philosophical systems which teach *the existence of timeless realms are more* akin to artistic visions than to scientific the ones The artist often projects his desires for a better world into his work Similarly, some philosophers seem to have been moti vated by unconscious emotional desires They reacted intensely to the fact that time passes irrevocably and that at the end of the time allotted to each of us there is death Their unconscious fear of death seems to have been transformed into fear of time, and this anxiety aroused the ardent desire to stop time's inexorable flux in order to escape death They attempted to achieve their aim of emotional gratification by projecting per manence onto "reality " According to them, temporality is only apparent, an illusion, or an inferior mode of existence There is a bet ter world, the "eternal" one Thus time's threatening aspect, its transitoriness, its persistent, irreversible flow in the direction of death, is denied, and the desire for per manence is appeased by the belief in an eternal reality which is impervious and in accessible to the ravages of time Since tem porality leads to destruction, it is often iden tified with the evil in the world If time is an illusion, evil can also be denied and regard ed as illusory

The mystics of all ages have declared that time is an illusion, both as an attribute of physical events and as an aspect of subjec tive experience, and they have preached that this illusion must be overcome Their goal in life is the mystical experience of a union with God, who is eternal, for whom there is no past and no future, who is com pletely removed from the dimension of temporality Immortality of the soul is the eternal union with God or existence in God's eternal realm

VII Summary

Aging is a process closely connected with time Thus this introductory chapter pro vides a theoretical foundation for all subse quent chapters Its purpose is to explicate the quantitative and qualitative properties of time

Subjective experience is not a reliable cri *terion for the determination of time metric,* time order, and time direction Therefore, a distinction has to be made between the psychological and the physical aspects of time

An analysis of the various objective prop erties of time shows that a further distinc tion must be made between expressions con stituting definitions and expressions consti tuting empirical assertions The concept of coordinative definition is introduced Only a combination of these two kinds of expres sions provides a complete description of physical phenomena

The metric definitions concern the unit of time the uniformity of time, and the zero point The choice of a definition may have a bearing upon the simplicity of the empiri cal description The notion of simplicity is explicated

A methodological discussion of different kinds of relations precedes the explication of time order (i e , the relations holding be tween events) Temporal order is reducible to causal order Two kinds of causal proc esses reversible and irreversible ones, are distinguished Time order can be established on the basis of reversible processes alone The reduction of time order to causal order leads to the relativity of simultaneity (i e , to an indeterminateness as to order of time for certain pairs of events)

The direction of time is explicated by means of irreversible processes The concept of probability is introduced, and the differ ence between causal laws and statistical laws is explained Reversibility and irrevers ibility are discussed in connection with the second law of thermodynamics The discus sion leads to the result that an intrinsic direction of time can be defined only with respect to ensembles of isolated systems This result presupposes an empirical as sumption, the hypothesis of the branch structure The assumption is formalized in terms of probability lattices

The direction of positive time is coordi natively defined as the direction of increas ing entropy in the majority of branch sys tems An application of this definition of an

intrinsic time direction to the entropy curve of a finite universe furnishes the result that time is pieced together of counterdirected sections

The statistical definition of the direction of time is extended to the macrocosm and leads to the distinction between producing and recording This distinction determines the choice between causal and teleological explanation The concept of a recording or registering instrument provides the connecting link between the objective properties of time and the time of psychological experience The subjectively experienced time direction of aging is found to be identical with the direction of increasing entropy due to the fact that man's brain functions like a registering instrument

Subsequent sections deal with the application of the concept of aging to inorganic and organic systems

The remainder of the chapter sketches the treatment which time and eternity have received in certain metaphysical systems

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III

Biological Periodicities, Mathematical Biology and Aging

HERBERT D LANDAHL

Time is inseparable from aging it may therefore be useful in organizing our thoughts about aging to consider the role of time in some biological processes Many processes are clocklike in their rhythmicity while others have a characteristic duration It

many tissues or processes themselves exhibit an intrinsic form of aging and this in turn reacts upon the organism as a whole To a large extent the study of aging consists of the measurement of variables of interest at various ages and the subsequent search for relationships among these variables Mathematics is an ideal tool for this latter undertaking and the construction of simple mathematical models can be useful in the understanding of the observed events Thus it may turn out that it is more useful to know the effect of age on a parameter of the model than the effect of age on the observed measurements since a change of a single value of the former may explain several kinds of observed effects In the physical sciences the derived constants are generally the more important quantities Although the stage may not as yet be set for any general mathematical theories of aging there is every reason to expect that certain isolated problems can be profitably treated in terms of mathematical models We shall therefore consider a number of biological phenomena in terms of their behavior in time under various environmental influences Mathematical models will be developed for several types of response and examples will be given where observable variables are related in terms of the model The organization will be in terms of classes of response rather than by subject matter although we shall try to emphasize problems which have been associated with studies of aging

I BIOLOGICAL TIME CLOCKS

NON PERIODIC CLOCKS

There is associated with most biological processes a characteristic time Some of these processes such as the survival times of the individuals of certain species under constant conditions show a rather narrow distribution A single individual can serve fairly satisfactorily as an hourglass to mark off an interval of time In contrast the survival times of certain reptiles amphibians and fish show a closer resemblance to the probability of survival of a radioactive isotope

The second relationship is more or less true for a considerable number of dissipative processes although some such processes require more than one time constant to characterize them adequately Even if the individual survival times are extremely erratic, the average survival time from a large population may serve quite satisfactorily as a clock We shall refer to the characteristic

time as the "time constant" of the process or occasionally give it as the closely related 'half life"

PERIODIC CLOCKS

may manifest itself as an irregular variation in time or as a regular oscillation which may be simple or complex There may or may not be a spatial distribution involved However, some sort of oscillatory behavior can be found at every level of biological organization—molecular subcellular, cellular, and tissue When the process is approximately periodic, the characteristic time is referred to as the "period"

At the molecular level Liesegang rings are an example of a repeated pattern in space (Liesegang, 1914) These rings can be produced by placing a small crystal of one substance onto a gelatinous layer which contains a second substance which forms a precipitate with the first As time passes, rings of precipitate are formed Although the pattern is very regular, neither the space nor the time shows a constant period A process which resembles this occurs in the development of dental caries (Coolidge *et al*, 1955) This appears to be largely an inorganic chemical process though it occurs in a biologically produced structure

Another physical chemical example is Lillie's (1932) iron wire model in which waves of depolarization travel along the wire at a constant rate These waves may be periodic, in which case this is an example of a regular periodic spatial pattern at a fixed time and a regular temporal periodicity at any given point

Examples at various biological levels are rhythmic contractions of vacuoles, the periodic aspects involved in cell division, the regular firing of elements of a sense organ, the beat of the heart, and many others In passing, one may point out that the regular discharge or firing of the sense organ, exposed to sudden stimulus, gradually changes to a different firing level If one treats the frequency of firing, which is regular over a short interval of time, as a variable, the change in this new variable itself has a characteristic time constant, an adaptation time Such an interplay between the periodic and the non periodic aspects is the rule rather than the exception in biology

It may be useful to give some additional examples of various types of biological clocks There are many phenomena which are too irregular to be classified as clocks Among these are such variables as daily body temperature and daily blood count (Steinhaus and Jenkins, 1930, Brues and Sacher, 1952) A process which shows a regular oscillation may have a simple wave form, as in the movement involved in shivering, or its form may be complex, as in the wave form of an electrocardiogram A third example of a regular clock is the chirp of the cricket, which has a constant frequency at a constant environmental temperature The frequency increases with temperature In the other two cases the amplitude is relatively constant, while the frequency changes markedly with temperature In the case of the electrical potentials from the heart, the wave form can be altered without much change in frequency or amplitude

COMPENSATED CLOCKS

In each of the examples above the frequency or the amplitude changes markedly with temperature On the basis of biochemical relationships one would expect a strong temperature dependence except perhaps in certain relatively small temperature ranges A process which is fairly independent of temperature over a wide range is analogous to a temperature-compensated clock (Bruce and Pittendrigh, 1956)

A biological example is the diurnal change in color of the fiddler crab (Brown, 1957*a*) These periodic changes persist in the absence of changes in light intensity, and the period is constant over a very wide range of temperatures Other examples of cycles with periods are the menstrual cycle and the sleep cycle which persist in the absence of diurnal changes in light intensity (Kleitman,

1939) In these latter cases the relative independence of the periods on external temperature and foods consumed are probably largely due to the precision of the homeostatic mechanisms which maintain the constancy of the body temperature and of the composition of the blood

CLOCKS WHICH SLOW DOWN WITH AGE

There are a number of processes through which a parameter is slowly changed with time Thus over a long enough period of time the elasticity of a steel spring will change, rubber will deteriorate, and various substances will polymerize A clock with a steel spring would slow down if given enough time for the spring to lose its temper

Consider a single process which decreases uniformly with time We might define the age of that process as the time from the beginning of the process, since there is a fixed relationship between the measure of the process and time The introduction of age in this case is of no value unless we are considering a group of items which are not all identical As an example, we may consider the deterioration of rubber by cross bonding The elastic limit of the rubber may be the property under consideration For a given set of conditions the elastic limit of a group of samples will have an average temporal pattern Individual samples may have slightly different compositions or may be subjected to slightly different conditions As a result we may say that one sample ages more rapidly than another By this we only mean that in a certain interval of time the first sample showed a greater change in the elastic limit than the second However in biological processes we may not know how to measure the variable which may correspond to the elastic limit in this example It may only be possible to measure the time at wh ch

processes analogous to wear and tear or to that given above are not applicable to aging because biological processes are in a state of flux While this is true, there are processes which do deteriorate with time Thus, even though repair processes are occurring with a resulting turnover in all the metabolites, some of the disruptive processes in the tissues of the mature organism always exceed the corresponding repair processes so that a steady state can no longer be maintained When some complex combination of these deficits reaches a threshold level, which depends on the environment, the average organism can no longer survive Alternately, we may say that, as the threshold is approached and passed, the probability of survival becomes progressively lower as time passes

II CLASSIFICATION OF PERIODIC AND NON PERIODIC SYSTEMS

Before considering some mathematical models of periodic and non periodic phenomena, we shall discuss some of the more important types of response systems In most quantitative biological investigations, measurements are made on a magnitude, on a duration or on a rate of one or more processes In the study of aging one may be interested in measuring the mass, length, and density on an organism or of a single organ Or perhaps the concentration of calcium and cholesterol in a tissue is measured at the same time that the magnitude of an electrical potential or the blood pressure is observed One may be interested in observing individual survival times or psychological reaction times On the other hand, one may wish to find out how nerve-conduction velocity, the rate of flow of blood through the brain, or the total metabolic rate changes with age We shall consider only one such dependent variable as being measured as a function of time

If the system under observation is kept under constant conditions for some time, the measured value of the variable will reach an asymptotic state This variable may be

indefinitely in some peculiar manner We refer to the former as a constant steady state In the latter case the system is in a periodic steady state if the variable settles down to a regular temporal pattern If the system shows small enough fluctuations, we may, of course, choose to ignore these and consider the state to be constant

CLASSIFICATION OF A STIMULUS RESPONSE SYSTEM

While a great deal of information can be learned by measuring various quantities characterizing the system being studied considerably more can be obtained by perturbing the system and observing the response of the variable (Bertalanffy, 1950, Trimmer, 1950) We consider only the case in which some parameter of the system is changed suddenly from one value (e g , its normal value) to another value, which is then maintained constant in some way for an arbitrarily long time T_1 At this time the parameter is suddenly changed back to its original value We shall refer to the change in the value of this parameter as a stimulus Since this parameter is thought of as having been changed by the observer it is a variable Since it can be changed independently, it is called an independent variable ' It will be noted that the above stimulus pattern has the property that for all times except at the moments when the stimulus is started and stopped, the only quantity

1

The behavior of the system can be used to subclassify each of the two kinds of systems (I) those with constant steady states and (II) those with non-constant steady states (cf Fig 1)

The system (I) which has a steady state under normal conditions may show the following types of response to the suddenly established stimulus (1) the variable establishes a new level (*a*) after a uniform change or (*b*) after a change in which the variable shoots past its new level and then approaches the new level; possibly with damped oscillations, (2) the variable may develop an oscillatory behavior The behavior of the response when the stimulus is withdrawn at time T_1 enables systems to be classified into (α) those in which the variable returns to its initial value and (β) those in which it does not This latter group which exhibit hysteresis can be classified into those in which there is (β') a new steady state level or (β'') those showing a permanent oscillatory behavior Some of these cases are illustrated in Figure 1, where the following notation is used P denotes periodic response, p the absence of oscillation, H hysteresis, h no hysteresis The symbols in parentheses refer to the interval in which the stimulus acts A subscript u or n means a uniform or non uniform approach to the new level Thus $p(P)h$ means that normally there is no oscillation, but, when the stimulus is applied, a periodic response is produced, when the stimulus is withdrawn, the response returns to its original value v_0 Similarly, $p(p_u)h$ means that normally there is no oscillation, the stimulus produces a uniform change to the new response level, and, when the stimulus is withdrawn, the response approaches a value v' different from v_0 In the figure the subscript o after H indicates that a permanent oscillatory behavior results from application of the stimulus

Systems of class (II) which normally show oscillation, may be classified into those which cease to be periodic during the stimulus period (cf curve $P[p]h$ of Fig 1) and those in which the amplitude frequency, or wave form are altered After cessation of the stimulus a system either will return to the original behavior eventually or will remain changed In the latter case the hysteresis may involve a loss of periodic behavior or a permanent change in amplitude, frequency or wave form

POTENTIALITY OF RESPONSE OF A SYSTEM

Any variable will have a classification which depends on the stimulus and its range as well as on the values of the various parameters which have been held constant

It is therefore also convenient to classify the potential behavior of a given variable system The values over which the various parameters can range is restricted only in a general way Thus they may be restricted to values compatible with life or to values compatible to the function of an organ

If there is a set of conditions under which the variable of a system can maintain oscillations, we may refer to it as a system with potential oscillation One would expect such a system to show damped oscillations when the parameters have values not too different from those in which there is oscillation Under these latter conditions, relatively small influences which can produce changes in the variable are able to make the system appear to be in a non periodic, fluctuating asymptotic state

If there are values of the parameters in which a temporary change in the value of a parameter results in a permanent change in the value of some variable the system has potential hysteresis This means that there are at least two possible steady state responses for at least one biologically acceptable condition One, both, or neither may be oscillatory A system of this kind is a necessary element in any model of learning A system which can exhibit hysteresis

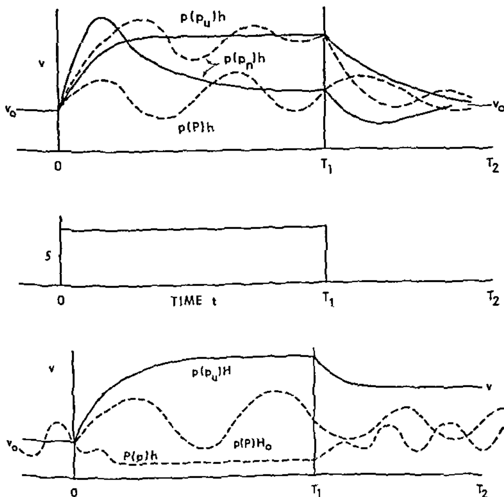


FIG 1 —Examples of stimulus-response patterns For details see text

has a threshold If the independent variable (the stimulus) is changed very slowly, the dependent variable (the response) follows it slowly At some value (the threshold) the response changes relatively quickly to a new value If the stimulus is withdrawn before the threshold is reached, the observed variable returns to its starting value But this is no longer the case after the threshold is exceeded Thus a bar which is standing on end is stable for displacements up to a threshold value Beyond this it will continue to fall spontaneously

A system which has neither of the above properties may be referred to as a uniformly simple system Examples from this simple system will be given in the next section

III Mathematical Models of Non periodic Phenomena

We shall next study some models mathematically in order to illustrate the types of response that can be expected to occur We restrict ourselves to those models which can be handled relatively easily In most cases

applications to non periodic phenomena

EXPONENTIAL SURVIVAL

As has been pointed out above, one of the simplest non periodic systems is that of radioactive decay where the probability of any molecule disintegrating is constant Any population of individuals in which the death rate is independent of time will show the same type of survival curve Let n represent the number of marked individuals at time t in such a population The number n will not include any individuals born into the population after the initial time $t = 0$ When it is desired to emphasize that n is a function of t, the notation $n(t)$ may be used If a large population is used, then the proportion of deaths within the small interval of time dt which lies between t and $t + dt$ will be almost the same as its probability The proportion is the decrease $-dn$, divided by the number (i e, $[-dn]/n$), dn being the number at $t + dt$, minus the number at t, $n(t + dt) - n(t)$ If we denote by k the constant probability of death per unit time, then the proportion of deaths, $(-dn)/n$, during the time dt will be kdt Hence we may write

$$dn/n = -k dt \qquad (1)$$

Both sides of equation (1) may be integrated to give

$$\log_e n - \log_e n_0 = -kt, \text{ or } \quad n/n_0 = e^{-kt}, \qquad (2)$$

where $\log n_0$ is an integration constant, n_0 being the value of n at $t = 0$ The second form in expression (2) is also frequently used to express the fact that in this case the survival fraction is a decreasing exponential function of age There is only one time constant in this system, the quantity $1/k$ This may also be given as the half life $0\ 69/k$ Since the probability of death does not change with time in this case, such a population shows no aging It may be noted that age does not enter other than as "clock time" A number of fish, reptiles, and amphibians do exhibit an exponential type of survival curve provided they have reached a minimum age

A MORE COMPLEX MODEL OF SURVIVAL

A more realistic model should take into account that the death rate for many species in the wild is much greater at early ages This could be accomplished in a formal manner by assuming k to be a function of age However, this is undesirable from a theoretical point of view, since it provides no explanation of the process The rate k must be thought of as being determined by the values of the various parameters of the organism and its environment An illustration of how this can be accomplished is given in the following example

In natural populations longevity is often determined to a large extent by competitive processes Physical size is a most important factor in survival, since the number of other

organisms which can prey upon it is an inverse function of its size In some cases this may be the dominant factor As an illustration only, we shall consider this factor to be all important We shall assume that, on the average, the environment is constant The organism, however, continues to grow Let the time t be measured from the time of [illegible]

[illegible]

given in terms of the model to be discussed in the next section However, to simplify the results somewhat, we shall introduce the following approximation

$$M = M_0 + \frac{r(M_\infty - M_0)t}{M_\infty - M_0 + rt}, \qquad (3)$$

so that the mass starts at M_0 and at first increases at a rate r, the rate of increase gradually decreasing toward zero in such a manner that the mass approaches M_∞

For the relation between death rate and size we introduce the simplest inverse relation, the reciprocal, so that, if k_1 is a constant, we have the death rate term k_1/M In addition, we may allow for death due to factors independent of size by introducing a term k_0 Then the death rate k is given by

$$k = k_0 + k_1/M \qquad (4)$$

It simplifies matters, without changing the form of the solution, to suppose that M_∞, the maximum adult weight, is considerably larger than M_0, the weight at birth Then, substituting expression (3) into (4) and the result into (1), we find, on integrating,

$$\frac{n}{n_0} = e^{-k_0' t}\left(\frac{M_0 - rt}{M_0}\right)^{-k/r}, \qquad k_0' = k_0 + \frac{k_1}{M_\infty} \qquad (5)$$

It will be observed that there are two time constants in the above expression One is $1/k_0'$, which largely determines the survival time for the larger organisms, and the other is M_0/r, which largely determines the survival at early ages It may be noted that for the case of indeterminate growth, in which $M_\infty \to \infty$, only the value of the parameter k_0 is modified

The above model is an example of survival where there is competition between a constant environment and a growing organism Though the result does coincide fairly well with certain survival data, it is emphasized that this is intended as an illustration only Furthermore, no senescence is in[illegible]

not most, wild species

It should be pointed out that for some purposes it is adequate to derive the relation between specific death rate and age from empirical data and then attempt to account only for this relation This procedure will often enable one to handle more complex relationships as well as to account for the effects of various internal and external factors One example of how this can be done will be given in the next section

POPULATION GROWTH

When a species is introduced into a favorable region, its numbers increase rapidly at first, but after a time it increases slowly The population ceases growing and may decline The population as a whole resembles an organism which grows, matures, and ages

In the last example the variable considered was the number of individuals surviving under fixed conditions for various lengths of time We consider next the situation in which organisms are introduced into a new environment of fixed dimensions where they can increase in number Differences between individuals, such as age, will be ignored Let N be the number at time t, N_0 being the initial number, $N_0 = N(0)$ We shall suppose that there is a constant specific birth rate, b, but that the death rate, being due to competitive factors, increases linearly with the number in the population $k = k_0 + \beta N$ The net rate of increase per organism is then the birth rate minus the death rate $b - k_0 - \beta N$ Note that, if the

birth rate decreases linearly with number because of crowding, the form of the equations is not altered If the quantity $b - k_0$ is represented by α, we then have

$$(dN/dt) / N = \alpha - \beta N \qquad (6)$$

On integration this gives

$$N = \frac{\alpha N_0 e^{\alpha t}}{\alpha + \beta N_0 e^{\alpha t} - \beta N_0}, \qquad (7)$$

so that N increases rapidly at first, generally with increasing rate, then more and more slowly, N finally approaching the value $\alpha/\beta = N_\infty$ This expression is the logistic curve, *the well known Verhulst Pearl equation* of population growth which has been satisfactorily applied to a number of situations (Pearl, 1922, 1925, Kostitzin, 1939) Since $\alpha/\beta = N_\infty$, we need only calculate α to know β But α i the only unknown parameter in (7) and hence can be easily estimated from the data Since the mean life of the organisms in the steady state is N_∞ divided by the birth rate, the measurement of one variable enables the estimation of the other

Expression (7) accounts only for the growth and maturation phases of the population However, if there are substances which are present in limited quantity in the environment, the population may decline and die out Suppose that one substance is the limiting factor and let Q be its amount at time t In general, both the birth rate and the death rate will depend on Q If the competition for Q is the more important effect, then we may consider the case in which β depends on Q Take the simplest case that $\beta = \beta'/Q$, the effect of Q on α being ignored The amount of Q at any time t is the amount Q_0 present initially, minus the integral over the time t of N times the utilization rate, a, per organism If the amount Q_0 is adequate for a sufficiently large number of generations, N can be considered to be equal to α/β Hence $\dot{Q} = -a\alpha\beta^{-1} = -a\alpha/\beta Q$ so that $Q^2 = Q_0^2 - 2a\alpha t/\beta'$ Since by hypothesis aN_0 is much smaller than α, we may substitute this value of Q into $\beta = \beta Q$ and the resulting β directly into (7), thus obtaining an expression giving the rise and decline of the population under the assumed conditions

We shall next use the example of the growing population to illustrate an approach which is analytic in contrast to the synthetic

From this curve calculate the time derivative of $N(t)$, $\dot{N} = dN/dt$, for various times t_1, t_2, These times have corresponding values N_1, N_2 , on the empirical curve We may now plot the points $(\dot{N}_1, N_1)$, $(\dot{N}_2, N_2)$, *that is the relation between the* time derivative and the population number (Kostitzin, 1939, p 198) In a population situation it is often more useful to plot $\dot{N}/N$ against N In the case of the *Drosophila* referred to above, one finds that this latter relation is roughly linear and hence expression (6), as well as (7), can be expected to account for the data The problem in this procedure is then to account for a relatively simple linear relation It should be pointed out that there may be more than one value of $\dot{N}$ for a given value of N This would occur if we are dealing with a population which declines When the relation is not single valued, then we must be prepared to look for changes in other factors

This case of population growth is an example of internal competition between equivalent individuals in a constant en

ly that of an organism, as will be discussed below The model can be generalized by considering individuals of different age groups to be different or by considering the interaction between different species Some attempts have been made in the first direction, and applications have been made to account for the temporal pattern of the population structure of the flour beetle (Landahl, 1955) Examples of the second will be considered in a subsequent section

SURVIVAL OF CLONES

We shall next make an application to a case which is of obvious importance to the problem of aging It has been shown by Lansing (1947) that there are factors in rotifers which can accumulate from one generation to the next and can result in the termination of the clone Furthermore, this effect can be reversed In these experiments the effects of interaction between organisms is not considered We shall therefore neglect them and consider only the changes within a single germ line We shall formulate the simplest model involving only a single factor determining the fertility of the egg Let this factor be present in the germ line in an amount z Let z be lost at a specific rate β which does not change with time If z represents the concentration of some substance, then β is the probability per unit time of a molecule leaving the cell or being changed by some reaction During embryological development we must assume that z is produced at some rate $a(t')$, t' being the chronological age To simplify matters, we shall suppose that the rate is constant from the time that the egg is laid until adolescence, a time τ later, thereafter it is zero We summarize this in the following expression

$$dz/dt = a(t') - \beta z\,, \qquad (8)$$

where

$$a(t') = a_0 \quad \text{for} \quad t' < \tau$$

$$a(t') = 0 \quad \text{for} \quad t' \geq \tau$$

The above expression may be integrated for any temporal pattern Consider first a τ orthoclone (Lansing, 1947) We shall refer to τ as the age of the orthoclone Let the value of z for eggs from a τ orthoclone have the value 1 After τ days z will be given, from (8), by

$$z = e^{-\beta\tau} + a_0\beta^{-1}(1 - e^{-\beta\tau})\,, \qquad (9)$$

this value of z pertaining to the germ line of the organism which is τ days old An egg laid on day τ by this adolescent organism has the same value of z as does its parent, since an adolescent orthoclone can be maintained indefinitely Hence $a_0 = \beta$ We shall take τ to be the age of the oldest orthoclone which can be maintained indefinitely

Next consider an orthoclone of age A, greater than τ, which has been initiated from a parent stock which is a τ orthoclone The parents started out as eggs with a mean value of $z = 1$ Eggs laid A days later initiate the F_1 generation They start out with a value $e^{-\beta(A-\tau)}$ These individuals develop, and the eggs that they lay on their Ath day, which start the F_2 generation, will have a value of z given, from (8), by

$$z_2(0) = e^{-\beta(A-\tau)}(e^{-\beta A} + 1 - e^{-\beta\tau}) \quad (10)$$

The eggs of the F_m generation will start out with the value

$$z_m(0) = e^{-\beta(A-\tau)}\{e^{-(m-1)\beta A} + (1 - e^{-\beta\tau})(1 - e^{-\beta A})^{-1} \times (1 - e^{-(m-1)\beta A})\} \quad (11)$$

We have supposed that z represents a factor necessary for development of the eggs If z is less than some value $1 - h$, the eggs can no longer develop This will occur at some generation F_G, so that we have

$$z_G(0) = 1 - h \qquad (12)$$

If β is small enough, expressions (11) and (12) reduce to

$$(A - \tau)G = h\beta^{-1} = \gamma \qquad (13)$$

From the data of Lansing (1947) on *Philodina citrina* we estimate that $\tau = 5$ days and $\gamma = 25$ day generations In Figure 2 the points represent the data and the curve represents expression (13) with the estimated parameters The agreement can be seen to be satisfactory If we do not assume that β is small, the results are somewhat changed The assumption is made only to simplify the result It may be pointed out here that had we assumed the regeneration rate to be of the form $a_0 z$, that is, proportional to the magnitude of z, then the above expression (13) would follow easily However, if an orthoclone of age $A < \tau$ is considered, then this latter model needs some modification, whereas the model under con

sideration does not This we proceed to show

Consider an orthoclone of age $A \leq \tau$ Let it start at some abnormal value ρ, where ρ may be more or less than 1 From (8) we can easily show that z for newly laid eggs of the nth subsequent generation will be given by

$$z_n(0) = 1 - e^{-n\beta A}(1 - \rho), \ A \leq \tau \quad (14)$$

From this we see that $z_n(0)$ approaches 1 after a few generations, the faster the closer A is to τ If $\rho = 0$, so that we start with eggs from young stock, then z remains equal to 1, provided only that the orthoclone is of age

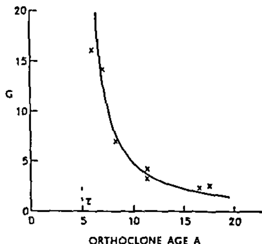


FIG 2—The number G of generations that a clone survives as a function of orthoclone age A *Curve* calculated from equation (13) with $\tau = 5$ days and $\gamma = 25$-day generations *Points* data by Lansing (1947, cf also chap v)

less than or equal to τ But we note that the agove expression determines the recovery rate of an orthoclone of age $A' > \tau$ which has not yet become extinct We need only substitute for ρ the value of z from (11) for the eggs of the first "reversal" generation which are the last eggs of the declining generation

Although we have considered z to be the magnitude of a necessary component in development, we could just as well suppose that it represents some detrimental factor In this case we need only change the signs of a, β, and h The results are not otherwise altered if β is small

While the above simple model may be able to predict the outcome of any arbitrary temporal pattern, it may also be able to account for a great deal more Since there are

some additional results may be obtained The threshold change, h, in z is actually an average of a distribution of values Instead of calculating only the mean value of G representing the terminal generation, we may estimate (1) the variability of G and (2) the probability of a given egg failing to develop, given the history of its germ line Both are governed by the same distribution It would then be of interest to determine if this distribution also largely determines both the distribution of the survival of individuals and perhaps also the number of eggs laid Most of the data of Lansing suggest that these two variables are both rather independent of A until the threshold is nearly reached If a common factor can be found, this would broaden the significance of the important findings of Lansing

TISSUE REGENERATION

We next consider the situation in which an organ can regenerate after part of it has been removed An interesting model has been given by Brues and Marble (1937) for the case of rat liver regeneration By postulating a delay of about one day and assuming that the total rate of increase in the number of cells is a constant minus another constant times the number of cells, it was possible to account for the early phase of regeneration We shall next consider a somewhat more general model which, although it may not account as well for the early phase, can account for such phenomena as the time delay and the "overshoot" in the regeneration process (Bucher and Glinos, 1950) This latter phenomenon is not too evident in the case of rat liver but occurs in other situations (for references see Norris *et al*, 1942, Bucher and Glinos, 1950)

The application of a special case of single organs during growth of an organism leads to the concept of heterogenous growth

(Huxley, 1932) On the other hand, we can consider the case of regeneration In this case an organ grows while the rest of the organism grows relatively slowly, if at all Since the growth of the organ is limited, the specific rate of growth must be reduced in some way as the size of the organ increases The organ itself may produce a substance which inhibits growth as in the case of the liver (Glinos and Gey, 1952) If the amount of this substance is y and if it inhibits the net specific growth rate k in a linear manner, the number of cells in the organ and the concentration of the inhibitor would be given by the following equations

$$(dN/dt)/N = k^* (y_\infty - y), \quad (15)$$

$$(dy/dt) = bN - cy, \quad (16)$$

where b is the rate of production of y per cell and c is the specific rate of loss of y through excretion and biochemical inactivation If b is large, so that the second expression above represents a process that is fast enough for it to be in a quasi steady state, then $y = bN/c$ But in the steady state $y = y_\infty$ and $N = N_\infty$ For simplicity choose the units of y to be such that $y_\infty = 1$ Then expression (15) becomes

$$(dN/dt)/N = k^* - k^* N/N_\infty \quad (17)$$

Comparing this expression with (6), we see that the solution is given by (7), with $k^* = \alpha$ and $k^*/N = \beta$ Thus we find

$$\frac{N}{N_\infty} = \frac{N_0 e^{k^* t}}{N_\infty + N_0 e^{k^* t} - N_0} \quad (18)$$

Note that there is but one unknown parameter, k^*, and that the model requires that the organ return to its original size Hence the model exhibits homeostasis The parameter N_0 is under the control of the experimenter

If we set $k^* = 0.4$ day^{-1} and $N_0/N_\infty = 0.32$, we obtain an expression

$$\frac{N}{N_\infty} = \frac{0.32 e^{-0.4t}}{0.68 + 0.32 e^{-0.4t}}, \quad (19)$$

which gives a satisfactory account of the data by Bucher and Glinos (1950) of weight of regenerating liver of adult rats in which 68 per cent of the liver was removed Young rats showed a more rapid growth rate than did old rats

It should be pointed out that, if the restriction that b should be large is removed, there will appear a greater lag at the start of regeneration but that there will also appear an overshoot before the final stable value is reached This point will be referred to subsequently in connection with the discussion of Figure 3B In the data cited there is little evidence for an appreciable lag in weight and only a suggestion of an overshoot, and this only for young animals Hence the time constant c^{-1} cannot be much more than about 2 days It can be shown that in the above case the introduction of $c = 1$ day^{-1} increases the time lag but introduces only a negligible overshoot According to Brues and Marble (1937), there is no increased mitosis for about 1 day Hence there must be an appreciable change in average volume per cell This factor complicates the interpretation of the data on organ weight We shall not consider this aspect further

It has been shown that the growth potential of rat liver decreases with age but that, when regenerated liver is used, there is no effect of age This effect is similar to that observed by Lansing Thus we might expect that after a few mitoses the loss in growth potential (e g, z of [13]) would be restored Hence one might suppose that k^* in (15) is proportional to z, z being given by (14), where ρ is a decreasing function of age If this is done, we find that a delay is introduced, the delay increasing with age Such an effect is not uncommon (Elman, 1952) This delay, however, does not appreciably influence the overshoot as does the delay due to the time constant c^{-1} We see, then, that the system of equations (8), (15), and (16), with $k^* = k'z$, can account for a considerable number of phenomena in at least a semiquantitative manner and that they enable one to understand how such phenomena as time delay and overshoot may be interrelated

INTERACTION BETWEEN SPECIES

We consider next the case where two species interact There are several reasons why this case is of interest to the problem of aging In the first place it is easy to see that the mean length of life of one species will depend upon the species with which it competes Second, it may be that such a system can serve as a prototype for the interaction of organs and tissues within an organism and thereby be of importance to the problem of aging of tissues Furthermore, this case serves to illustrate a number of different behavior patterns which can be exhibited by response systems

Suppose we have two species each of which is governed by expression (6) when they are kept apart But, when they are allowed to live together, there will, in general, be an interaction Let c_1 be the effect on the net specific birth rate of species 1 by each organism of species 2 Then, if the subscripts denote the species we have

$$\frac{1}{N_1}\frac{dN_1}{dt} = a_1 - b_1N_1 + c_1N_2 \qquad \text{(I)}$$

$$\frac{1}{N_2}\frac{dN_2}{dt} = a_2 - b_2N_2 + c_2N_1 \qquad \text{(II)} \qquad (20)$$

If, for example, c_2 is positive, then the first species is beneficial to the second, if negative, the interaction is detrimental to the second species Thus, if c_1 and c_2 are both positive, this would be called a case of symbiosis If one is positive and the other zero, this would represent a saprophytic relation If both are negative, this corresponds to mutual competition If one is positive and the other negative, we have a representation of parasitism

Except for some special relations among the parameters, the variables N_1 and N_2 will show a non periodic response We shall illustrate some types of response possible from the above system of equations To do so, we shall use a graphical method which is often helpful in complex systems If we set $dN_1/dt = 0$ in (20), we have a linear relation between N_1 and N_2 Along the straight line representing this relation, N_1 does not change with time We shall denote this line by I in Figure $3A$ In this figure we represent a case in which c_1 and c_2 are positive The parameters a_1, a_2, b_1, and b_2 we shall suppose to be positive in all the following cases Consider a point above the line I This can be reached by increasing N_2 only But from the first equation (20) it is clear that dN_1/dt is now greater than zero, since we have increased the last term Hence in any region above line I, dN_1/dt will be positive, and therefore N_1 will increase with time Conversely, it is evident that, for a point below the line, N_1 will decrease A similar argument can be given to show that, above line II, N_2 will decrease, while, below, it will increase The arrows in Figure $3A$ indicate these results It can be seen that if the lines I and II intersect, the intersection point represents the final stable value and that it is attained regardless of the starting position, provided only that neither N_1 nor N_2 is zero at the start The condition that there be an intersection is just that the slope of I must exceed that of II, that is, $b_1b_2 > c_1c_2$ If this condition is not satisfied, there would be no limit to the increase of either population

In Figure $3B$ is given an example of parasitism In this case it can be seen that there will be an asymptotic value for N_1 and N_2 but that the values will be approached [illegible]

there will be no intersection In this case the population 1, the host, will die out In this connection we may add parenthetically that equations (15) and (16) discussed in the section on regeneration give a graphical result somewhat similar to that of Figure $3B$ when b is finite Hence in the case of regeneration the asymptotic value may be approached by oscillations

Figures $3C$ and $3D$ are examples of competition, c_1 and c_2 being both negative The first case occurs if $a_1/|c_1| > a_2/b_2$ and $a_2/|c_2| > a_1/b_1$ This implies that $b_1b_2 > c_1c_2$ It can be seen that there is an intersection which represents the values of N_1 and N_2 in the asymptotic state, and this is approached without oscillations The second

case occurs if $a_1/|c_1| > a_2/b_2$ and $a_1/b_1 > a_2/|c_2|$ This implies that $a_1^2/b_1|c_1| > a_2^2/b_2|c_2|$ In this case population 2 becomes extinct It has a lower ratio of the net birth

sidered in the section on oscillatory phenomena For further detailed considerations of population interaction the reader is referred to the studies of Kostitzin (1939) and Lotka (1925)

AN APPLICATION TO WOUND HEALING

We consider one more population problem which is of interest in the study of aging The ability of tissues to repair damage is a

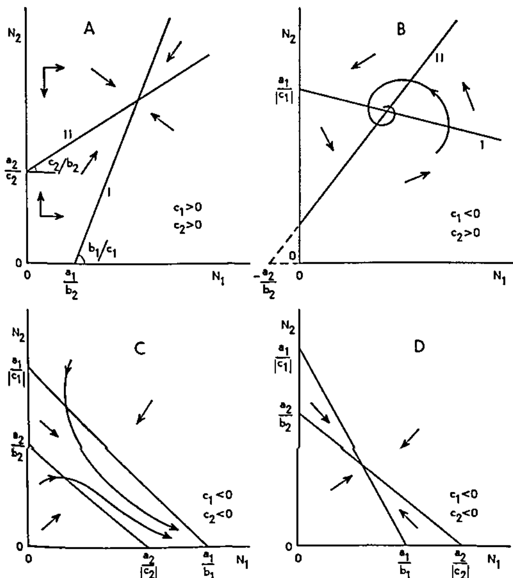


FIG 3—Graphical solution for equations (20) representing interaction between two species *A* symbiosis *B* parasitism *C* and *D* competition

physiological necessity for the maintainence of the organism The ability to repair damage at the cellular level not only changes with age but the repair process itself may act to counteract the effect of aging (Glinos and Bartlett, 1951) as in the case of endomixis (Jennings 1938) The growth potentialities of various tissues in tissue culture also decrease inversely with age (cf Glinos and Bartlett, 1951) Similarly, the rate of regeneration decreases with age, although the mitotic index shows a more complex temporal pattern (Bucher and Glinos, 1950)

Some aspects of the problem of repair of damaged tissue have been treated quantitatively by Lecomte du Nouy (1937), skin being the tissue used Equations were derived which reproduced the data satisfactorily and enabled conclusions to be drawn which

shall attempt here to give an example of how this objection can be met

The work on wound healing in man referred to above has been criticized on the following grounds (Elman, 1952, Comfort, 1956) First the data are too meager and not adequately controlled Second, rats do not show the decrease with age Third, healing is not important surgically, the important element being the tensile strength provided by the fibroblast activity (Howes and Harvey, 1932), an aspect which does not show a pronounced age effect Fourth, as mentioned above, the mitotic index does not decrease systematically with age The first criticism is a valid one However, in view of the great differences between organs and between species, the second and third can at the most introduce some doubts The fourth objection can easily be seen to be unimportant In the steady state, the mitotic index gives an indication of turnover or replacement The index in rat liver, for example, at rest is about 1/15,000 as compared with 1/150 at the third day after removal of two-thirds of the liver (Brues and Marble, 1937) The ratio is of the order of magnitude of 1 to 100 Though not so stated, it is for this reason that a replacement rate (death rate) term was not included explicitly in equation (15) In the above model such a term could vary over a considerable range without influencing the regeneration rate appreciably This is what occurs in the case of rat liver For this reason one should not expect any firm relation between mitotic index in the steady state and that during regeneration or growth While the first criticism may very well be valid, the case of wound healing does serve to illustrate how quantitative data can be treated in terms of a simple theoretical model in such a way so that the data are compactly summarized and some insight into the mechanism of the process is obtained

Dermal cells cease cell division, except for replacement, only when surrounded by other dermal cells in a layer of intact skin When a piece of skin is removed, the cells begin to divide rapidly The stimulus must be due to direct contact or to an interaction which acts at small distances If the piece removed has a relatively smooth contour, it is evident that at the cellular level the edge will rough and the curvature of the piece on the macroscopic scale will not show at the microscopic level Thus it need not concern us here whether a cell surrounded by cells on three quadrants is stimulated less than a cell surrounded on two On the other hand, there may very well be stimulating or inhibitory influences, produced by cells, which may diffuse throughout the system The effect of such factors would clearly be influenced by the shape and size of the wound

An empirical equation —Before attempting to develop a mathematical model we first develop an empirical expression which summarizes most of the data relating the area of the unhealed wound to the initial area, the time, and the age of the subject From the observations it was found empirically that the decrease in wound size $S' - S$, in 4 days was rather accurately given by (Lecomte du Noüy, 1937, pp 85 and 150)

$$S - S = BS\,(4 + \sqrt{4 + t})\,S_0^{-1/2} \qquad (21)$$

Note the change in notation, t being re

placed here by its numerical value 4 and nt being here replaced by $t + 4$ The 4 is added here so that the time t in days can be measured from the beginning instead of from the end of the 4-day interval The coefficient B can be given as a function of age A by the following approximate expression

$$B = 0.50\, e^{-0.031A} \qquad (22)$$

This equation represents the data as well as that given by Lecomte du Nouy (1937, p 167) and is easier to interpret The expression $S - S'$ is really a rate of decrease of area and very nearly equal to $4\,(-dS/dt)$ Introducing this expression for $S - S'$ in (21) and integrating, we have, on introducing (22),

$$S = S_0 \exp\left\{ -\frac{e^{-0.031A}}{2\sqrt{S_0}} \times \left[t + \frac{1}{6}(4+t)^{3/2} - \frac{4}{3} \right] \right\} \qquad (23)$$

This expression then enables one to calculate the wound size as a function of original size S_0, the time t, and the age A of the patient The results are very satifactory except that for very small wounds, less than about 10 cm^2, the older individuals heal somewhat faster than would be indicated by the calculated values Expression (23) is a useful summary of the measurements given However, it is the purpose here to consider a model which may give an explanation of the observed results

The simplest model —If we ignore the possibilities of interaction mentioned above, then the heal[illegible] consists

open wound be ρ, ρ_0 being its initial value Then the distance of advance of the edge is the decrease of the radius of the open wound If the constant rate of linear growth is denoted by g, then the decrease in radius, $-d\rho$, which takes place in a short interval of time dt, will be gdt Thus

$$-d\rho = g\,dt\,, \qquad \rho = \rho_0 - gt \qquad (24)$$

Since a wound will only be approximately circular, it is more accurate to measure the area Let S and S_0 be the areas corresponding to ρ and ρ_0, $S = \pi\rho^2$ Then the second expression (24) can be written

$$S = (\sqrt{S_0} - \sqrt{\pi}\, gt)^2 \qquad (25)$$

Note that this expression gives the area S as a function of time t for a given initial size, and at any time t it gives the area as a function of the initial area S_0 If these relations are compared with the data, it is found that the first relation is satisfactory for small wounds For large wounds the theoretical relation breaks down after healing has progressed for some time However, the initial rate which is given by differentiating (25),

$$(dS/dt)_0 = 2\sqrt{\pi}\, g\sqrt{S_0}\,, \qquad (26)$$

shows the correct relation to the initial area of the wounds over a wide range of sizes For example, the parameter g, calculated from (26), using the data (Lecomte du Nouy, 1937, Figs 15, 20, and 21) for the 20-year-old normal subject, has the values 0.10, 0.11, 0.11, 0.09, 0.11, and 0.11 cm per day for the corresponding initial wound areas of 10, 20, 30, 40, 40 (*ibid*, Fig 20), and 130 cm^2

A model with interaction —In the absence of independent evidence in regard to mechanisms which determine healing rates we may take two approaches First we may consider simple cases of plausible interaction and compare the theoretical results with the observed On the other hand, we may estimate the empirical function, giving the relation between the rate $d\rho/dt$ and a dependent variable such as the radius of the open wound, its area, area of the healed wound, or the time integral of one of these variables Such a relation can be obtained by calculating the rate from the data for selected times and the eliminating time by plotting the estimated rate against the value of the chosen variable at that corresponding time Suggestions may arise from the form of such curves

The simple model with constant g accounts for the data down to about 3 cm^2 for initial areas up to 40 cm^2 Below an area of

about 3 cm² the rate drops considerably This suggests that there is a stimulating effect of the unhealed area which, however, saturates at a low value which is in order of magnitude of 3 cm² This must be fairly sharp, and hence an area dependence will provide a simpler explanation than if the radius is considered If a substance has a steady state concentration c proportional to the wound area and if this substance acts as a substrate in an enzyme reaction, then the rate would be proportional to $c/(c + K_m)$, K_m being the Michaelis Menten constant of the reaction Thus we shall replace g by $g_0 S/(S + h)$, h being a constant not far from 3 cm², and $g_0 = g$ when $S \gg 3$ Instead of (24) we have as the second approximation

$$\frac{d\rho}{dt} = -\frac{g_0 \pi \rho^2}{\pi \rho^2 + h} \qquad (27)$$

so that ρ and hence S, is determined from the expression

$$\rho_0 - \rho + \frac{h}{\pi} \frac{(\rho_0 - \rho)}{\rho_0} = g_0 t \qquad (28)$$

A value of 2 for h is in agreement with the data It may be pointed out that the initial rate of healing is not much changed by this additional factor unless the initial area is less than about 10 cm² This factor also improves the agreement between theory and experiment for small initial areas

There remains the range of disagreement for very large initial areas which, however, only shows up when the wound has been reduced to about 25 cm² This suggests a small factor which enters as a function of the healed area $S_0 - S$ and which therefore does not show up unless the initial area is large Such a factor might arise if the healed area competes for an inadequate blood supply Since the factor is not large, we must be satisfied to use a linear approximation Since the effect decreases the rate, we introduce a factor 1 minus a constant times $(S_0 - S)$ If this constant is $1/S^*$, then, instead of (27), we have

$$\frac{d\rho}{dt} = -\frac{g_0 S}{S + h}\left[1 - \frac{(S_0 - S)}{S^*}\right], \qquad (29)$$

an equation which can be integrated It can be shown that this equation can account for the data on young subjects for wound sizes up to 130 cm² if $g_0 = 0\,11$ cm/day, $h =$ 2 cm², and $S^* = 370$ cm² Note that this expression implies that for wounds greater than about 400 cm² the wound will stop healing at a certain finite size The size of the wound at which this actually may occur is not given (Lecomte du Noüy, 1937, p 84)

There then remains the problem of the effect of age of the subject We shall not consider the effect of wound shape The older subjects show a marked decrease in the rate of growth This could occur because there are less cells dividing properly or because they divide at a slower rate The latter could be due to substances carried in the blood (cf Glinos and Bartlett, 1951) Consider first the former possibility Let n be the number of undifferentiated cells per unit area which can contribute to the healing process We suppose that this number density is in a steady state, the cells being used in repair as needed Suppose that there is a certain chance, which we take to be constant over the years, that such a cell is accidentally converted into a cell which can occupy space in the determination of the number n but which cannot contribute to tissue repair Then if these faulty cells, on the average, give rise to like cells, it can be seen that, while n is constant, the number of effective cells is an exponentially decreasing function of age (Lecomte du Nouy, 1937, p 225) Hence, on this model, the coefficients g_0 and g_0/S^* are presumably both the same exponential function of time if there is no secondary effect of age on the parameter S^* Thus, introducing numerical values from these data, we have $g_0 = 0\,20$ $e^{-0\,031A}$ Note that in this case mitosis does not appear to restore "vigor" as in the case of liver or *Philodina citrina* so that the value of A in equation (14) must be very small in this case This case is a special case of group (2*B*) discussed in the next to-the-last section of this chapter

Consider next the possibility that the decrease in growth rate is due to increased

average time between cell divisions This could be due to inherent factors or to sub stances carried in the blood stream They may be either increased amounts of inhibi tory substances or decreased amounts of necessary substances Consider the latter case, since it gives a somewhat simpler, though similar, result If there were just a fixed amount of some substance and each molecule had a constant probability of loss, the result would be that the material would decrease exponentially with time But it is more likely that the substance is produced at a rate determined by the number of molecules of some self reproducing enzyme If these occasionally fail to reproduce exactly, then certain proportions of the sub stances normally produced are either not produced or, if produced, not effective It is clear that this situation is equivalent to that of the preceding paragraph if n now repre sents the number of self reproducing enzyme molecules *instead of cells* Thus it can be seen that an exponential decrease of g_0 with age is very plausible

The measurements of wound healing agree very well with equation (29), where g_0 is *the exponential function given above An* exception may be that there is an under estimation of the healing rate in the older subject with very large initial wounds (not shown in Fig 4, cf Lecomte du Nouy, 1937, pp 85-86) *A comparison for young subjects* is made in Figure 4, using several initial areas One curve for a 40-year-old subject is also given

AN EXAMPLE FROM THE THEORY OF THE CENTRAL NERVOUS SYSTEM

We next give an illustration from a model of the nervous system In this section we present it only as an example of a response system A possible application to aging will be given in a later section

The two factor theory of the excitation (ε) and [illegible] ellent

1948) The following pair of equations were proposed by Rashevsky (1948) to represent the temporal aspects of the stimulating ef fect of a group of neural elements which terminate on the afferents of a second group

$$d\epsilon/dt = a(\phi - \epsilon),$$
$$dj/dt = b(\psi - j), \tag{30}$$

where $1/a$ and $1/b$ are time constants, and ϕ and ψ are similar monotonic functions of

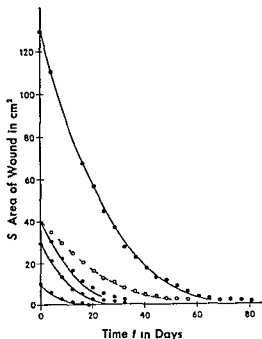


Fig 4 —Area S of wound as a function of time

small effect

some stimulus S The notation is somewhat simplified (21) It is assumed that $\epsilon - j$ is the net excitation acting on the secondary group of neural elements Hence it is of interest to follow the value of $\epsilon - j$ in time If we choose the temporal pattern for the stimulus used in Figure 1, we can obtain the typical results shown in Figure 5 The re strictions on the parameters for each curve are given in the legend Curve A cor responds to the case in which there is a

simple excitatory effect In curve B the net excitation rises rapidly and then settles down to a steady value as long as the stimulus is maintained Such a situation occurs in the continuous elements of the retina In this connection attention should be drawn to the Brücke effect (Householder and Landahl, 1945, p 47) After cessation of the stimulus there is a transient inhibitory state In curve C there is only an "on" effect while curve D corresponds to a situation in which there is a transient inhibitory

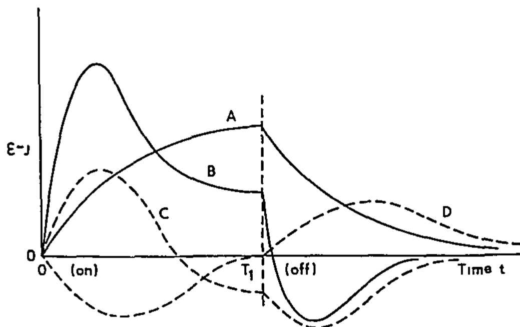


FIG 5 —Response patterns for the net excitation $\epsilon - j$ from equations (30) for on and off stimulation

effect while the stimulus acts, but at cessation there is a transient excitatory effect This corresponds to the off activity due to the retinal photoreceptors (Householder and Landahl, 1945, chap 1) It has also been used to account for the anodic break excitation in nerve (Rashevsky, 1948, chap xxiv)

While for a single element one obtains non periodic phenomena, much more complex behavior can be obtained when one considers interacting elements A few examples will be considered subsequently

IV Mathematical Models of Some Periodic Phenomena

Simple Oscillation Due to Inertia

One of the simplest physical examples of periodic phenomena is that of a weight fastened to a spring To lift the weight above its equilibrium position requires an upward force proportional to the distance from the equilibrium position Similarly, to pull the weight below this point requires a force which is the greater, the greater the displacement Thus, when the weight has an upward displacement x, the net force on it is downward or negative and proportional to x Owing to this force, there is an acceleration, d^2x/dt^2, such that the mass (m) times acceleration equals the force

$$m\,(d^2x/dt^2) = -kx\,, \qquad (31)$$

k being the proportionality constant measuring the stiffness of the spring It can be easily verified that $x = A \sin 2\pi\, t/T$ satisfies the above expression if $T = 2\pi\sqrt{m/k}$ and if A is an arbitrary constant The

weight can therefore oscillate indefinitely with a period T such that the displacement is sinusoidal, the maximum displacement being arbitrary

If we recognize that there is always resistance to motion, it is clear one should introduce a term representing a force of resistance, proportional to the velocity, for example, $R(dx/dt)$ When this is introduced, then, for a small resistance, the only change is that x becomes multiplied by $e^{-Rt/2m}$ The periodic motion is now slowly damped, the time constant of this process being $2m/R$ There are now two time constants, one of which pertains to a periodic process, the other determining how long it takes for the oscillations to damp out

When the resistance term is very large, there is no longer a periodic component but only two exponential time constants L/R and R/k The effect of the first disappears rapidly, leaving only the second, which can be seen to arise from the differential equation if the acceleration term is ignored

Biological applications of the above occur in the case of muscular movements The oscillation in shivering has a period governed in part by the considerations in the first case above The speed of walking has been assumed to be governed by the period of a limb acting as a pendulum (Thompson 1945), although a more realistic model requires consideration of muscular forces (Hill 1927, Rashevsky, 1948 chap li) On the other hand, the motion of the otoliths is an example of the second case

INTERACTING SYSTEMS

Although the second order differential equation has applications to biological problems, periodic phenomena are more likely to arise as a result of interaction The simplest case of linear interaction with two variables can be shown to lead to a second order differential equation Only under special conditions can oscillations be maintained (Rashevsky 1948 chap vi) With non linear interaction, oscillations can be obtained more easily An application to periodic relapsing catatonia may be of interest (Danziger and Elmergreen, 1954) We shall next consider some examples of non linear equations

Parasite host interaction —Consider a special case of the interaction given in expression (20) which was first given by Volterra (1931) Suppose that the death rate of the host is dominated by the action of the parasite but its specific birth rate is constant Then a_1 is positive, but c_1 is negative Let the parasite have a natural death rate but a birth rate which is proportional to the number in the host population Thus a_2 is negative, and c_2 positive For this case the graphical procedure, illustrated in Figure 6, shows that there can be a periodic behavior A biological example of this case is the interaction between *Paramecia* and yeast observed by Gause (1934, cf Lotka, 1925, Kostitzin, 1939)

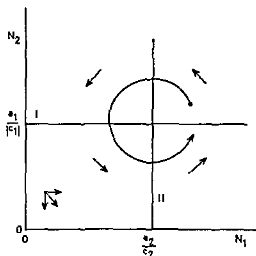


FIG 6 —Graphical solution for equations (20) representing a special case of parasite host interaction which gives periodic solutions for the population numbers as a function of time

A model of periodic excitation in nerve — Let x and y represent the concentrations of potassium in an inner (I) and an outer (II) layer of a nerve membrane, both being measured in terms of the external concentration (Karreman and Landahl 1952) Let the concentration within the nerve fiber be 50 in these units The flow per unit area from

the inside into Region I is the product of a permeability and the concentration difference $(K - x)$ Similarly, the flow from Region I to II is the product of a second permeability times the difference $(x - y)$ The flow from Region II out into the external medium is proportional to the diffusion coefficient times the difference $(y - 1)$ The two permeability coefficients are themselves dependent on the concentration in the neighborhood because of the effect that potassium has in loosening the membrane structure This effect is such that the permeability is proportional to the square of the concentration over a range of values The increase in x with time is given by the difference between the flow in from the inside and the flow out into Region II In this way we find, if ρ and r are constants,

$$
\begin{aligned}
dx/dt &= \rho x^2 (50 - x) - y^2 (x - y) \\
dy/dt &= y^2 (x - y) - r (y - 1)
\end{aligned}
\qquad (32)
$$

The constants ρ and r are functions of the calcium concentration because it also affects the membrane permeability It is found that for low values of the calcium concentration the parameters are such that there is a permanent oscillation in which one phase is narrow and high while the other phase is shallow and broad This can be seen by using the graphical method outlined above If the calcium concentration takes on successively larger values, this oscillation will suddenly cease For a range of values the system shows a threshold behavior Small displacements, as might be produced by momentary electrical currents cause a perturbation which quickly subsides But a perturbation beyond a certain threshold value produces a response in which the concentration change continues to increase even in the absence of the stimulus Associated with this concentration change is an electrical potential This excitation pulse returns after a short time to the original value If the calcium concentration is increased still more, the system can show neither excitation nor oscillation The equations (32) therefore show some of the properties of nerve, including the correct type of dependence on the calcium concentration

RELAXATION OSCILLATIONS

If a parameter of a system changes nearly in a stepwise manner with a variable or if one process in a system is very rapid under certain conditions, an inherently complex system can sometimes be handled fairly simply We shall refer to the oscillations of such systems as relaxation oscillations

Some simple models—The most well known model of such an oscillation is the clock Here the oscillation of a system, governed by an expression like (31) with a very small damping term, is prevented from stopping by an escapement mechanism which applies a small force through some small part of each cycle Thus the actual equation has an additional force term which is zero except at certain times In the steady state the energy imparted during each cycle will equal the energy loss due to the resistance term If the amplitude should drop below the steady state value, the frictional loss, which is dependent on the velocity, will now be less and thus less than the imparted energy The amplitude will therefore increase toward the steady state value

If we think of cell division as occurring when a threshold size is reached, the division process being fast compared with the intervening growth, this process represents a relaxation oscillation in which the period is simply the time required to grow from one-half the critical mass to the mass at which division occurs (Rashevsky, 1948, p 197)

A sense-organ model—In the last example the frequency of the oscillation can be controlled by any parameter which changes the growth rate Since the frequency of impulses is used in the nervous system to indicate intensity, it may be of interest to consider a simple model of an intensity-controlled relaxation oscillation The results from this model will be used subsequently

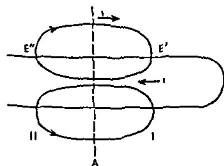
A terminal portion of a nerve is represented schematically in Figure 7A If, for

any reason, the potential difference across the membrane in Region II is greater than that across Region I, $E'' > E'$, current will flow as indicated This is a cathodic current with respect to the membrane at II and, if large enough, could produce an excitation in which the membrane resistance R_2 of Region II drops suddenly to so low a value that we can set $E'' = 0$ (Curtis and Cole, 1944) This excitation can then propagate as an impulse down the nerve

Let the electrical properties of the nerve membranes be as shown in Figure 7B Furthermore, if the current i exceeds some value i^*, R_2 suddenly becomes nearly equal to zero The effect of a stimulus might be to change E or to increase the permeability of the membrane We shall consider only the latter possibility and let $E_1 = E_2$, $r_1 = r_2$, and $C_1 = C_2$ In the absence of the stimulus let R_1 be a fraction F_0 of R_2, $F_0 < 1$ When the stimulus S acts, R_1 changes to some value FR_2, where F is a function of the stimulus being equal to F_0 for $S = 0$ If we suppose for the moment that there is no breakdown process in the membrane, then the current i will have the steady state value i_∞ given by

$$i_\infty = \frac{rR_2E(1-F)}{(R_1+R_2)\,r + rR_T\,(r+R_2) + (2R_2r + R_2R_T + rR_T)\,R_2F} \qquad (33)$$

If $F = F_0$, then i_∞ may be greater or less than i^*, depending on the value of F_0 If $i_\infty > i^*$, we have a case of spontaneous activity, which is modified by the stimulus occurred For simplicity suppose that R_T is small enough so that both potentials E' and E'' become negligible Now the current i having become zero, R_2 is restored to its



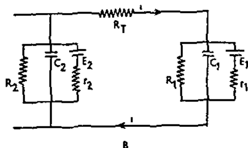


Fig 7 —Electrical representation for a sense-organ model

If $i_\infty < i^*$, there is no activity unless the stimulus exceeds a threshold This latter will always occur if F_0 is too near 1 The threshold can thus be decreased by decreasing F_0 so that the system becomes sensitized

We next suppose that the change in permeability, or conductance, is proportional to the stimulus so that

$$F^{-1} = F_0^{-1} + aF_0^{-1}S\,, \qquad (34)$$

aF_0^{-1} being the proportionality constant Suppose that $i_\infty > i^*$ for some S Let t be zero when the breakdown process has just ordinary value The potentials can now begin to develop Again, for simplicity, suppose that one time constant, which is of the order of magnitude of rC, is adequate to represent the recovery, or approximately

$$i = i_\infty(1 - e^{-t/rC}) = (i_\infty/rC)\,t + \qquad (35)$$

[illegible]

$i = i^*$ to obtain the time t^* between impulses Let S^* be the value of S for which

$i_\infty(S^*) = i^*$ The reciprocal of t^* is the frequency, f

$$f = \frac{1}{rC}\frac{i_\infty}{i^*} = \frac{(1 - F_0 + aS)(A + BaS^*)}{(1 - F_0 + aS^*)(A + BaS)} \quad (36)$$

where

$$B = r^2(R_1 + R_2) + rR_T(r + R_T), \quad A = B + 2F_0R_2(2rR_2 + R_2R_T + rR_T) \quad (37)$$

Here the linear relation (34) between the membrane permeability and stimulus intensity has been introduced This then gives an approximate relation between frequency of firing and the stimulus intensity in terms of the parameters of the nerve and nerve ending The frequency increases linearly, with S for small S, then increases more slowly There is an upper limit which can not be exceeded regardless of the intensity If there is spontaneous activity, S^* will appear as a negative quantity

It should be noted that the stimulus S is not the external stimulus but that which acts in the membrane In the case of mechanical stimuli, as in pressure, proprioceptive, and labyrinthine stimuli, this could conceivably be a direct effect of distortion But, in the case of visual stimuli, S would very likely be the concentration of an early photochemical intermediate produced by the action of the light In this case the above model gives a rather satisfactory account of a great variety of visual phenomena In this connection it may be pointed out that a result similar to (36) is obtained if it is supposed that the electromotive force E, instead of the resistance R, changes due to the stimulus S (Kamiya, 1958) In the case of temperature receptors one can consider that E, which represents the effect of active transport mechanisms, is dependent on temperature through reaction rates, so that a representation of temperature by frequency of firing is obtained The results from this section will be used in the last part of this chapter

V Mathematical Models of Hysteresis Phenomena

We next discuss some examples of phenomena in which the response and the state of the system depends not only upon the immediate past but also upon events which may have occurred far enough in the past that all transient effects will have disappeared Thus, for example, if a constant current is passed through a coil around a piece of iron the degree of magnetization will be different, depending on whether the current had been increased from a small or negative value or whether it had been decreased from a larger value In this example the process is reversible In some cases it is not It may be that the latter case is more important in the processes of aging However, we shall consider the first case, using an example from the theory of the central nervous system (Rashevsky, 1948)

Neural Elements in a Closed Circuit

Closed circuits are of common occurrence in the central nervous system The simplest theoretical case is that of a neural element which acts on itself, the element being of a simple excitatory type (Householder and Landahl, 1945, p 22) Let there be an external stimulus S acting on the afferent end of such an element There will also be an amount ϵ produced at its own efferent endings which also acts upon itself The net excitation is then $\phi(\epsilon + S - h)$ h being the threshold Hence from the first expression (9) we have

$$\frac{d\epsilon}{dt} = a\,[\phi(\epsilon + S - h) - \epsilon] \quad (38)$$

for example Let $d\phi/d\epsilon$ be greater than 1 when the argument of the function ϕ is zero Then if we plot ϕ against ϵ, as in Figure 8, for the case in which $S = 0$ (*solid curve*) and a line at 45°, we find that the curves intersect at two points The first

curve starts from zero at $\epsilon = h$, since S is zero, and hence $\epsilon - h + S = 0$ at this point In the region to the left of ϵ' the ϕ curve is below the 45° line representing $\epsilon = \epsilon$ Here ϕ is less than ϵ, and hence, from (38), $d\epsilon/dt$ is negative, and ϵ will decrease with time if it is somehow given a positive value less than ϵ' But between ϵ' and ϵ^*, ϕ is greater than ϵ, and hence $d\epsilon/dt$ is positive so that ϵ increases It cannot pass ϵ^*, since at this point $d\epsilon/dt = 0$ Beyond ϵ^*, ϕ is again less than ϵ so that a displacement into this region will result in a return to ϵ^*, in the absence of an external stimulus If the external stimulus S is greater than some threshold value, the ϕ curve will be displaced an amount S to the left, as indicated by the dotted curve in Figure 8 Now ϕ is greater than ϵ from 0 to the value ϵ^{**}, and hence ϵ will become equal to this value after a time If now the stimulus S is withdrawn, ϵ will not return to its initial zero value but will move to ϵ^* and remain there indefinitely This will be the case unless some other factor such as fatigue is taken into account or unless some random inhibitory effect interferes Thus this example exhibits hysteresis

A similar situation can be obtained if we consider McCulloch Pitts (1943) neurons occurring in closed circuits If we suppose that the action of each element is adequate to stimulate the next one and if we ignore fatigue, there are two possible states for the circuit If they are all at rest, they will remain so But, if once one is stimulated, there will always be some element in the circuit which is acting

A MODEL OF CONDITIONING

We next consider briefly an application of hysteresis to the phenomenon of conditioning Possible applications to age changes in learning will be mentioned subsequently We shall consider the simplest possible model (Rashevsky, 1948, chap xxxvii) Let a stimulus S_u, the unconditioned stimulus, act upon the afferent end of a neural element, I, which forms a neural connection with a final common path having a threshold h If this value is exceeded, the response R will be produced There may be many synaptic connections involved, but we consider only a representative one Let S_c represent a stimulus, the conditioned stimulus, which cannot produce R by itself initially Let S_c act on a neural element II which connects with an element III, having a threshold h_3 and this in turn connecting with the final common path Since S_c cannot produce the response, then, if $\phi_{II}(S_c) < h_3$ for all S_c, this condition is satisfied Let there be a collateral from I, having an associated func-

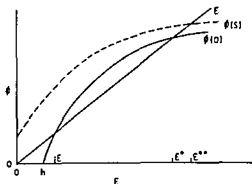


FIG 8 —Graphical representation of equation (38) illustrating hysteresis in a closed neural circuit The quantities ϵ and ϵ^* represent the unstable and the stable values of ϵ when $S = 0$ $\epsilon = 0$ also being a stable value The quantity ϵ^{**} represents the only stable value when S has a sufficiently large value

tion ϕ_I, which terminates at the connection between II and III Let this connection also be part of a closed neural circuit which has a threshold h^* which must be exceeded in order to bring the circuit into permanent activity Then if $\phi_I(\infty)$ (i e, $\phi_I[S_c]$ for large

nearly the same time as S_u, and if $\phi_I(S_u)$ + $\phi_{II}(S_c)$ exceeds h^*, the closed circuit will be set into continuous activity Now, when S_c and S_u are withdrawn, there remains this excitation, ϵ^* If ϵ^* is less than h_3, the response will soon cease But, after S_0 and S_u have been given together, the application of S_c alone now gives an excitation of $\phi_{II}(S_c)$ +

ϵ^* If this exceeds h_3, the element III will become active, and a response will occur if the threshold between III and the final common path is not too high The conditioned stimulus is now able to produce the response

It is more realistic to suppose that there are actually a number of elements like III with associated circuits with distributed parameters so that a number of nearly simultaneous repetitions of S_c and S_u may be needed This enables one to develop expressions for performance in a learning situation in which a number of parameters enter Some of these can be varied experimentally In this way it is possible to derive expressions for the number of errors in a recognition learning situation as a function of the independent variable, the number of trials, as well as in terms of the variable parameters, the number of possible choices, strength of reward or punishment, and delay times For a recall learning situation, an expression for the number of failures to respond can also be obtained as a function of the independent variable and the experimentally controlled parameters (Householder and Landahl 1945, chap xi)

VI A Formal Model of Physiological Aging with Application to Human Mortality Data

In a previous section we discussed some survival curves in terms of interaction In human populations and in some laboratory animal populations the interaction plays a secondary role We therefore consider a situation in which interaction is ignored except as it enters indirectly We shall consider only two classes of factors The first class arises because many hazards result in an immunity This is more or less true of most diseases It is also true of certain accidents which if survived are thereafter avoided The second class of factors are processes associated with aging We shall see that these factors can account for the main features of a mortality curve for humans (cf Pearl, 1922)

Immunity Processes

Consider a single hazard which results either in death or in immunity Let p be the probability per unit time (year) of its occurrence, and let m be the probability of death The probability of death within a short time Δt of an individual who is not immune is $mp\Delta t$ After 1 year the probability of an individual being immune is $(1 - p\Delta t)^{1/\Delta t}$, after 2 years it is $(1 - p\Delta t)^{2/\Delta t}$, etc Hence the specific mortality k_1 at the Ath year is

$$k_1(A) = (mp)(1 - p\Delta t)^{A/\Delta t} = mpe^{-pA}, \qquad (39)$$

the last expression being obtained by letting Δt approach zero

Actually of course, there are many diseases, and not all are equally frequent or have the same mortality An inspection of the mortality curves suggests that we may be able to group these into two groups (1) those that are so frequent that by 1 year of age most of the population is immune and (2) a second group which can be grouped together or which has a frequency such that most individuals are immune by about the tenth year Since the mortality is low, we can simply add the two terms, each of which is of the form of (39) This can be shown to account for the data satisfactorily

However, more generally, we may suppose that there is distribution of p values If the m values are not correlated with the p's, we can factor out a mean value of m and ignore $\bar{m}$ for the time being We would then have a series of terms, $p_1e^{-p_1A} + p_2e^{-p_2A} +$ If these p's form a geometric series, then we can approximate the sum of the series by an expression $(p_1 + p_2 + \quad)/(1 + KA)$, K being a constant The value of K depends mostly on the first and largest value of p, though it does also depend on the ratio between the consecutive ps For example, for p_1, p_2, , having the values 4, 0 4, 0 04, , the K is about 10, while the sequence of values 4, 1, 1/4, , K is about 7 When the first term is 4 and the ratio between consecutive terms is 2, K is

about 3, while for a ratio of $\sqrt{2}$, K is about 4 Hence Λ gives an indication of the ratio between terms If $p_T = p_1 + p_2 + \quad$, the sum of the initial probabilities, then the net contribution to the mortality is approximately

$$k_1(A) = \bar{m}p_T/(1 + \Lambda A) \qquad (40)$$

We have not explicitly considered any interaction in the population However interaction does enter through the probabilities, for example, contacts in dense populations increase the likelihood of a hazard and may also indirectly increase the mortality, since a disease starting before complete recovery from another may have a greater probability of mortality Such factors need to be considered when one attempts to interpret the parameters in terms of the individual hazards This will not be attempted here

AGING PROCESSES

All physiological parameters change with time, and practically all are held in the neighborhood of some mean value by some homeostatic mechanism The latter mechanism may change with a resulting systematic change On the other hand even when there is no systematic change there are still changes of a random nature We shall treat this problem in a very elementary manner For a more detailed treatment the reader is referred to the work of Sacher (1956, 1958) Consider a parameter, v, which tends on the average toward v For simplicity suppose that the parameter is observed only at intervals which are long enough apart so that we can no longer predict an observation from the last one Let σ be the standard deviation of a sufficient series of measurements of v We can expect that the probability of observing a given value v_1 of the parameter will be given by $p(v_1/\sigma - v/\sigma)$, where $p(x)$ is the normalized error function

$$p(x) = \frac{1}{\sqrt{2}} e^{\quad x^2/2} \qquad (41)$$

Many parameters, such as blood pressure or red cell count, must remain within certain limits for life to be possible The limits are themselves interrelated A very low red cell count may increase the danger of a very low blood pressure Furthermore, the limits depend on the environment A low red cell count that would not be fatal at sea level might be at a high altitude Or the simultaneous occurrence of a very low white cell count and an infection might be fatal, whereas the low count alone and the infection when the count is normal may each be tolerated This means that there is a complex surface in a many dimensional space which separates the space into that part which is compatible with life and that which is not The experimental task of determining such a surface is very great We shall *simplify matters by considering only those* parts of the space which can occur with an appreciable frequency and suppose that these are independent Those will occur with the largest frequency which have the least distance from the mean to the limit V_i, $V_i - v$ compared with the variability σ_i, that is the least $(v_i - v)\ \sigma_i$ If there are a number of such factors with values which themselves distributed more or less randomly then the result tends toward that which occurs with only one factor Hence the results obtained on the basis of a single variable are not unlikely to approximate a real system The decomposition of the approximate, simple representation into the component parts requires data much of which are not as yet available

We consider, then, a single variable v with mean value v and standard deviation σ The quantity v represents an average of various independent variables weighted by the ratio of the standard deviation to the distance between the normal and the threshold limit Let V be the value of the single limit below which the homeostatic processes are unable to operate To simplify matters, we consider that there is a limit V on the lower side only The limits V_i which determine V are effectively altered by chance events in the environment, such as exposure to infection or severe trauma Such events may result in the death of some individuals Suppose that such events occur with an

average interval longer than that necessary to insure that the population reacquires a normal distribution of v values following a loss due to the previous chance event We may then consider that the distribution of v in the population remains approximately constant To simplify matters, let variability in V be included in σ, so that we may treat V as a constant

Some physiological parameters decrease in efficiency with age few, if any, increase In this model these will contribute toward a decrease in v In addition, in some functions the range over which homeostasis can effectively operate is decreased with age, while in few if any, does the range increase Hence the V may increase with age, narrowing the range which can be tolerated It has been suggested on the basis of a more detailed model that the variability increases with age (Sacher, 1958) Any one of these factors could change with age as a result of imperfect recovery from previous insults Summarizing these statements mathematically, we have

$$v(A) = v_0 - \alpha A + \quad , \qquad (42)$$

$$V(A) = V_0 + \beta A + \quad , \qquad (43)$$

$$\sigma(A) = \sigma_0 + a A + \qquad (44)$$

Note that we have supposed that the above quantities change from birth This is simpler to do Essentially the same result is obtained if they are started at age 15

HUMAN MORTALITY CURVE

At an age A, the probability of observing a particular value v is given by $p(v/\sigma - v/\sigma)$, the function $p(x)$ being defined by (41), v and σ being given from (42) and (44) The probability of death within a unit time will be proportional to the probability that v has a value less than V given by (43) This probability k_2, which depends on age, is given by the sum of the probabilities of all $(v - v)/\sigma$ values in which v is less than V Hence it is the integral of $p(x)$ from its most negative value, $-V/\sigma$, to $-(v - V)/\sigma$ Since V/σ turns out to be so large, we can replace $-V/\sigma$ by $-\infty$ with no appreciable error Hence, using only the first-order terms in (42), (43), and (44), we find

$$k_2(A) = \int_{-\infty}^{-(\bar{v}-V)/\sigma} p(x)\,dx = \int_{-\infty}^{-a+bA} p(x)\,dx, \qquad (45)$$

where

$$a = (v_0 - V_0)/\sigma_0, \qquad b = (\alpha + \beta)/\sigma_0 + (\bar{v}_0 - V_0)\,a/\sigma_0^2 \qquad (46)$$

It can be shown that, to a fair degree of approximation, for negative values of y

$$P(y) = \int_{-\infty}^{y} p(x)\,dx = 6\ 3\,e^{2\ 8y}, \quad 0\ 0005 \lesssim P \lesssim 0\ 05 \qquad (47)$$

This covers the most important part of the annual mortality range for humans Since, from (45), $k_2(A) = P(y)$ for $y = -a + bA$, the value of $k_2(A)$ can be found from

$$k_2(A) = 6\ 3\,e^{\ 2\ 8a} e^{2\ 8bA} \qquad (48)$$

We use this form, since it is somewhat easier to use in estimating the values of the parameters Also one can then give the proportion surviving at age A in a closed form Hence, as the mortality terms are small, we may obtain the total mortality age curve by adding the above term (48) to expression (40) Comparing with the data of Pearl (1922), we find the following expression for the total mortality k to be satisfactory over a wide range

$$k(A) = 0\ 060/(1 + 6A) + 0\ 00055\,e^{0\ 065A} \qquad (49)$$

A comparison with data is shown in Figure 9 The agreement can be seen to be more than satisfactory It should be pointed out that hazards which are outgrown even without exposure to them will resemble an immunity process From expressions (48) and (49) it can be seen that $a = 3\ 3$ and $b = 0\ 023$ Hence the single equivalent variable starts at $-3\ 3$ in units of the standard deviation and decreases, on the average, by 0 23 units or 0 7 per cent per year At about

82 years the value has reduced to about one-half that at age 20 Note that this latter value includes the effect of the increase in V and σ It should also be noted that the mortality data are given as of the beginning of the year, and hence, if the constants are to be estimated, the discrepancy of a half year in the midpoint of the class interval should be taken into account This is very important in the first term, relatively unimportant in the second, and much less so in the last Note that we have neglected mortality factors which are independent of age Since the age A is just the time t from birth, we may substitute k from (49) into equation (1) and, upon integrating both sides, obtain n/n_0 the proportion surviving, as a function of age

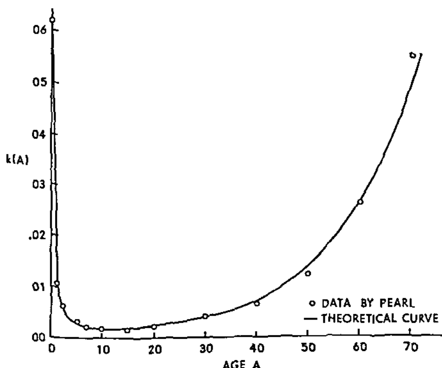


FIG 9 —Human mortality curve *Points* data by Pearl (1922) *Curve* equation (49)

It should be emphasized that we have introduced time explicitly, and there remains the problem of an explanation of this process We shall next consider this very briefly We may classify tissues into two main groups (1) those which have a negligible turnover of cells, as in the central nervous system, and (2) those in which there is an appreciable turnover of cells In group (1) are the tissues in which the number of cells can only decrease as a result of accidents The resulting decrease in the number of cells may then contribute to the decrease in v and an increase in V In addition, the depletion of critical duplicating molecules may result in loss of function in the remaining cells Group (2) can be divided into two subgroups In group (2A) are those tissues in which a steady state fails to be maintained so that the number decrease This decrease may then result in decreased function, which, in turn, may increase mortality In addition, there may be transmitted effects superimposed on this trend These effects will be discussed in the next paragraph In group (2B) are those tissues in which there is no substantial decrease in numbers The only way in which tissues in this group can show intrinsic changes with time is through transmitted changes We

shall consider any changes resulting from an intrinsic change in another tissue as being subsumed under the primary change

If the renewal rate is too small, there could be an accumulation of somatic effects, resulting in decreased efficiency But, regardless of the magnitude of the renewal rate, there may be an accumulation of changes which are transmitted, such as genetic changes We next consider a classification of these effects Some of these will require but a single event to manifest its effect, as in the case of a dominant genetic character These latter may be classified into three groups (*a*) those which result in a negative net gain, k, which is appreciably less than zero (*b*) those in which the net gain is almost exactly zero, and (*c*) those in which the net gain is positive Events in group (*a*), though they may be rather frequent, are soon lost, because k is negative Group (*b*) will by its very definition depend to some extent on the length of time being considered, since the group can include more changes if relatively short times are being considered If the renewal of cells is appreciable, the transmitted changes of group (*b*) can be maintained Since most random changes would be expected to result in some malfunction, these changes which can accumulate in time will result in a reduction of the function except in rare instances The transmitted changes of group (*c*), though rare, will soon displace the normal cells as in a neoplastic growth In very rare instances these might be beneficial If they are no worse than normal, they will produce no easily observed effect Generally, however, they will be detrimental

Other changes which can be transmitted may require an event to be repeated for an effect to be manifested, as in a recessive genetic character While two events are needed to obtain the change in function, it may require only one event to change the net gain k Hence this group may be classified into the groups (*aa*), (*ab*), , (*ij*), , (*cc*), where (*ab*) means that the first event results in $k < 0$ as in group (*a*) of the last paragraph, while the repetition of the event makes $k = 0$ again, as indicated by the second symbol *b* The second event must, of course, occur before the cells subjected to the first event have been lost from the population

In case (*b*) the decrease in function will be exponential if the probabilities of the events are independent of time and if we consider only detrimental effects It should be noted that special cases of exponential decreasing functions were discussed above in the section on wound healing To a first approximation an exponential decrease can be taken to be linear if V_0 is not too small compared with v_0 Case (*ab*) is similar to case (*b*) after an initial period These cases are then the justification for the linear approximation used above It should be added, however, that the relatively rare events of groups (*cb*), (*bb*), and (*ic*) result in altered function which changes with increasing rate with age, and this could account for the fact that the calculated values fall below the observed values when the age exceeds 70 years

The similarity in the effects of aging and those of exposure to radiation has been frequently pointed out (Sacher, 1956, 1958, Upton, 1957, Yockey, 1958) Radiation at sublethal levels will have little effect on tissues of group (1) We consider only the effects on cells of group (2) The effects classified in groups (*a*) and (*ia*) will be of a transient character and hence will be important only in acute effects Recovery from these will be complete The effects of group (*a*) should be proportional to the dose, while those of (*ia*) should be proportional to the square of the dose, both being dependent on dose rate The effects of group (*b*) will be permanent, proportional to the dose, and independent of dose rate, showing no recovery Those of groups (*ib*) will depend on the square of the dose and on dose rate but will leave a permanent change Those of groups (*c*) and (*ic*) will show changed similar effects to those above except that there will always be delayed manifestations Note that it is evident that, for groups (*ci*) spaced doses are more effective than a single dose if comparisons are made at equal times measured from the last exposure

It is clear from the above discussion that

to a first approximation we may consider the long term effect of a certain amount of irradiation is equivalent to the passage of a certain amount of time, since these both contribute vectorially to a decline in the equivalent single variable $\bar{v}$ which determines mortality On the other hand, since the effect of a dose depends upon the temporal pattern of its delivery, obvious qualifications have to be made For the situation in which case (*b*) is a dominant factor, a dose of radiation can be directly related, in terms of the present model, to a loss of a proportional number of days from the life expectancy, and the loss will be relatively independent of the temporal pattern of exposure But to the extent that case (*bb*) is important, small doses will have a disproportionately small effect, and the exposure pattern will be of importance

VII A Model for Some Psychological Effects of Aging

We shall next consider how a simple postulate as to the effect of age on one parameter might account for changes in a number of psychological variables The phenomena we shall discuss are flicker fusion, simple reaction time as a function of intensity, and choice reaction time as a function of difficulty Since there is a decrease in the number of neurons with age (Thompson, 1917) but no appreciable change in conduction velocity, fiber diameter, etc (Birren and Wall, 1956), we shall postulate that the number of nerve fibers in a pathway (or the number of neurons upon which they act) is the only parameter that changes with age Although other factors may be just as important, it is of interest to consider this effect alone

A Model for Critical Flicker Frequency Phenomena

If we wish to have a mechanism which responds only to change in intensity, it is clear that this can be most easily obtained by setting $\phi = \psi$ in expressions (30) above For simplicity let $a \gg b$ in these expressions If we have an intensity I which is on for a time $\frac{1}{2}T$ and off for $\frac{1}{2}T$ and if this cycle is repeated, j will soon be approximately at its mean value $\frac{1}{2}\psi$, since it changes very little during a moderately rapid alternation of light and dark But ϵ increases and decreases during this time, since a is large When a steady state has been reached, ϵ will have some value, ϵ_0, at the moment when the

exponentially, starting at ϵ_1, by hypothesis, and hence during the off period

$$\epsilon\,(\text{off}) = \epsilon_1 e^{-at} = \epsilon_1 (1 - at) + \quad , \quad (50)$$

if t is measured from the time the light goes off But at $t = \frac{1}{2}T$, $\epsilon = \epsilon_0$ again, since the light comes on then Hence, if $t = \frac{1}{2}T$ in (50), we have

$$\epsilon_0 = \epsilon_1 - \tfrac{1}{2}\epsilon_1 aT \qquad (51)$$

During the light period ϕ is a constant, so that we have

$$\begin{aligned}\epsilon\,(\text{on}) &= \epsilon_0 e^{-at} + \phi\,(1 - e^{-at}) \\ &= \epsilon_0 (1 - at) + a\phi t\,,\end{aligned} \qquad (52)$$

where t is now measured from the time the light comes on But at $t = \frac{1}{2}T$, ϵ is again ϵ_1 by hypothesis, since the light then goes off Hence

$$\epsilon_1 = \epsilon_0 (1 - \tfrac{1}{2}at) + \tfrac{1}{2}a\phi T \qquad (53)$$

From (51) and (53) we may solve for ϵ_1 and find $\epsilon_1 = \frac{1}{2}\phi$ approximately Hence since $\phi = \psi$, $\epsilon - j$ is on the average zero However, from (51),

$$\epsilon_1 - \epsilon_0 = \tfrac{1}{2}\epsilon_1 aT = \tfrac{1}{4}\phi aT \qquad (54)$$

Thus $\epsilon - j$ varies between $-\frac{1}{4}\phi aT$ and $+\frac{1}{4}\phi aT$ Let h_f be the threshold of the center upon which $\epsilon - j$ acts Then if $\frac{1}{4}\phi aT$ exceeds h_f, there will be a response otherwise not, that is, "flicker" or "no flicker" For a given ϕ that frequency $f = 1/T$ which just makes the largest value of $\epsilon - j$ equal to the threshold will then correspond to the critical flicker frequency, f^*, so that $f^* = a\phi/4h_f$

The quantity ϕ is thought of as the total number of impulses transmitted over a pathway per unit time and is therefore the number of fibers times the frequency per element The latter is roughly proportional to the logarithm of the intensity I Hence we have

$$\phi = \beta N_1 \log_{10} I/h \,, \qquad (55)$$

h being a threshold intensity, N_1 being the number of fibers, and β being a constant Then we may write

$$f^* = (\beta N_1 a/4h_j) \log_{10} I/h \,, \quad (56)$$

an expression which contains the well-known Ferry Porter law which states that the critical flicker frequency is approximately proportional to logarithm of the intensity (Householder and Landahl, 1945, p 45) Note that we have assumed that the frequency is not too low, otherwise the approximations used in (50) and (52) are not valid

If we measure the slope of f^* versus $\log I$, the threshold h does not enter We are considering age as changing only N If so, then N is proportional to the slope Data by Coppinger (1955) give the following values For subjects in their twenties f^* is 18 cycles per second for 0 09 millilambert and 40 75 for 1 74 millilambert, for subjects in their seventies the corresponding frequencies were 12 72 and 31 64 The slopes are then 17 6 and 14 6 and in the ratio 1 20 1 From this we shall estimate that $N_{1Y}/N_{10} = 1\ 20$

SIMPLE REACTION TIME

Since we have supposed that $a \gg b$, for calculating a reaction time, we may ignore j We shall consider the following model An intensity I acts as a stimulus on receptive elements which lead to a center of threshold h_1 This in turn leads to an efferent connection of threshold h_2 Now let the stimulus be suddenly established and maintained Suppose that the activity ϕ_1 in the afferent is immediately established Then the second element is being stimulated by an amount ϕ_1 We shall suppose that the incoming number of fibers is large so that the second element can be saturated For this we use (36) with $F_0 = 1$, $A = B = 1$ Hence the activity (frequency) in pathway 2, ϕ_2, is given by

$$\phi_2 = \frac{N_2(\phi_1 - h_1)}{1 + a(\phi_1 - h_1)}, \qquad (57)$$

N_2 being the number of fibers in pathway 2 Let ϵ_2 be the state of activity at the efferent of the second pathway, so that

$$\frac{d\epsilon_2}{dt} = a\phi_2 - a\epsilon_2 \,, \qquad (58)$$

$$\epsilon_2 = \phi_2 (1 - e^{-at})$$

Setting $\epsilon_2 = h_3$, the threshold of the third pathway which we consider to be a final common path, we find the time, t_R, when the response occurs

$$t_R = \frac{1}{a} \log_e \frac{\phi_2}{\phi_2 - h_2} = \frac{1}{a} \log_e \frac{N_2}{N_2 - a h_2} \qquad (59)$$

$$+ \frac{1}{a} \log_e \left[1 + \frac{h_2}{N_1 \beta (N_2 - a h_2) \log_{10} \bar{I}} \right],$$

where

$$\log_{10} \bar{I} = \log_{10}(I/h) - \log_{10}(I_h/h) \,, \quad (60)$$

$$\log_{10} \frac{I_h}{h} = \frac{h_2 + h_1 (N_2 - a h_2)}{N_1 \beta (N_2 - a h_2)}, \quad (61)$$

ϕ_1 being the same as ϕ in equation (55) and I_h being the observed threshold intensity Note that this threshold is increased if either N_1 or N_2 decreases

In Figure 10 we have set $N_2/ah_2 = 50$ *and* $aN_1\beta = 2$, *and* $a^{-1} = 7.5$ *to obtain the* simple reaction time curve labeled *S—Young* The points along this curve are from Cattell (1886, cf Householder and Landahl, 1945, p 39) and are used as a reference only The upper scale on the abscissa pertains to these points If we suppose that $N_{10}/N_{1Y} = 0\ 83$ and also that $N_{20}/N_{2Y} = 0\ 83$, we obtain the curve labeled *S—Old* Here the abscissa is $\log_{10} \bar{I}$ If the threshold is not adjusted for, then, even if h does not change, the curve is displaced to the right, but the amount is negligible for this numerical case if we neglect h_1 in (61) If, for

example, h is changed by a factor of 2, the dotted curve is obtained

It can be seen that at high intensities the reaction times, *Old* to *Young*, are in proportion to N_{2Y} to N_{20} but at low intensities the ratio is larger because of the effect of Y_1. This effect becomes appreciable only when the intensity is very low

It should be pointed out that we have ignored conduction time and motor time sponses are mutually exclusive, the simplest model is to suppose that, in addition to the two separate chains of pathways postulated in the last section, there is an inhibitory pathway from each chain to the other. Thus not only let the first pathway corresponding to stimulus A give an activity ϕ_A acting on the second pathway of its own chain but let it act inhibitorily by an equal amount on the second pathway of the chain

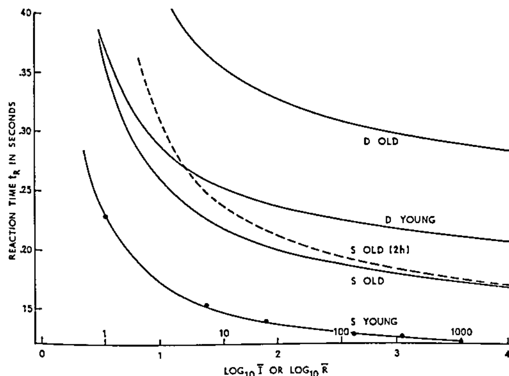


FIG 10 —Simple reaction time and discrimination reaction time as a function of stimulus intensity or of stimulus intensity ratio calculated from equation (59) for two age groups

In a previous formulation these were considered to be large (Householder and Landahl 1945, p 39). When data are available on the various components of the reaction time as functions of intensity, the values of the parameters will be more meaningful

DISCRIMINATION REACTION TIME AS A FUNCTION OF DIFFICULTY

When there are two stimuli of intensities I_1 and I_2, each with a response and the re- corresponding to stimulus B. Then instead of ϕ we have $\phi_A - \phi_B = N_1\beta \log_{10}(I_1/I_2)$ at the first connection of the chain corresponding to stimulus A, if stimulus A is greater than B. When a choice situation is presented, it may be necessary that the threshold h_2 be increased to h_2' to prevent an effect, not due to the difference, from occurring. One may also expect a larger value for h_2' from the following argument. The value h_2 can be controlled to some extent centrally, since increased attention and

motivation can decrease the reaction time In the case of a choice reaction, the same central control must be directed to decrease two separate thresholds As a result h_2' could be greater than h_2

The choice reaction time is now given by the same expression (59) as for the simple reaction time, except that h_2 is replaced by h_2' and that $\log_{10} I$ is replaced by $\log_{10} \bar{R} = \log_{10}(I_1/I_2) - \log_{10}(I_1/I_2)_h$ The threshold $\log_{10}(I_1/I_2)_h$ *the value below which the* subject must guess is given by the right hand side of (61), h_2 being replaced by h_2 Curves for discrimination reaction times are also given in Figure 10 h_2/h_2 being taken as 1 5 In this case the threshold (I_1/I_2) is considerably increased, the corresponding $\Delta I/I$ values being 5 3 per cent and 3 6 per cent and thus in the ratio 1 46 to 1 For these estimates the threshold h_1 has been set equal to zero If this is not done then the ratio 1 46 is reduced toward 1 2 But when the subject must guess the ratio of $\Delta I/I$ between old and young does not depend on h_1 or h_2 and reduces to about 1 2 to 1 Note that from the figure it can be seen that, on the basis of the model the ratio of the reaction time between old and young is fairly constant unless the task is quite difficult and the ratio is about the same in both situations These results may be compared with the data on choice reaction by Birren and Botwinick (1955)

If the variabilities in simple and choice reaction times are principally due to fluctuations in the threshold h_2 then the relative variability in reaction time should be nearly the same in both situations unless the task difficulty is too large When the threshold is approached the problem is more difficult In the case of flicker, the variability would depend upon the variability of the threshold h_f Here we assume that the total number of impulses within a time less than $1/a$ is very large If not, then the statistical fluctuation in the frequencies would have to be considered Because of relation (57) and the numerical values used, the contribution to the variability at h_2 from this source is considerably greater than that at h_1 and thus might account for the observed differences But since these variabilities are, respectively, about 10 and 20 per cent for the simple and choice reaction times, this would mean that there would be only about 100 or 25 impulses, respectively, in the utilization time Even if this time is taken to be as low as 20 milliseconds, this corresponds to some thousand impulses per second for only 25 or 100 fibers at 50 cycles per second in each of the two respective cases In this connection it is appropriate to draw attention to use of such considerations by Gregory and Crane (1955) to account for the effect of area and intensity in threshold phenomena

DISCRIMINATION AND LEARNING

Consider next the situation in which a difficult choice must be made We use the simple model described in the last subsection ignoring reaction times Let there be any combination of random threshold fluctuations, fluctuations in the value of any ϕ, or random inputs into either chain As implied above, it is these fluctuations which largely determine the variability of the reaction times as well as the variability in flicker response The main results of experiments on discrimination can be accounted for with this model Householder and Landahl, 1945, chap ix) For intensities which are not too large, the precision of a discrimination (dP/dS, P being the probability correct) in the two-category situation is found to be proportional to N_1N_2/σ, where σ is a weighted average standard deviation of the fluctuations Thus any age change in discrimination should be roughly proportional to the age ratio for reaction time if σ does not change If σ is largely determined by the statistical nature of ϕ_2 then σ is proportional to $\sqrt{N_1N_2}$ In this case the discrimination would vary as $(N_1N_2)^{1/2}$ and hence would vary somewhat more rapidly with age than would reaction time

If recognition learning is considered as a discrimination among stimuli whose effective magnitudes can be changed by conditioning (Householder and Landahl, 1945,

chap xi), then the rate of learning is roughly proportional to $(\phi_2/\sigma)b$, where b represents both the number and the quality of the circuits available for conditioning (cf discussion above under Sec V, "Mathematical Models of Hysteresis Phenomena") Since we are considering that it is only the number of neurons which change, the parameter b would be proportional to a number N_3 of neural circuits, and hence the rate of learning should decrease with age more rapidly than discrimination by a factor N_{30}/N_{3Y}

While the above model is oversimplified, it does serve to show how a single effect of aging can alter a number of psychological responses in various amounts Furthermore, it suggests how age changes may be used as a tool in helping to understand some of the mechanisms underlying various phenomena

VIII Summary

In this chapter some aspects of the role of time in biological systems are discussed Many functions show a periodic behavior, but even one which does not may have a characteristic time associated with it In the first section various kinds of biological time clocks are discussed

If a function is perturbed by experimental manipulation, its temporal behavior gives information about the underlying mechanisms A single time constant may be adequate to describe the process if the function simply returns to normal However, the function may not return to its original state Oscillations may be produced or normally occurring oscillations may cease Such possibilities are discussed in the second section

Mathematical models of some nonperiodic systems are given in the third section These are used to illustrate the manner in which some problems associated with aging can be formulated in quantitative terms Among the topics discussed are the survival of individuals of a population, the survival of clones, and the regeneration of tissues

In the next two sections mathematical models are given to represent some examples of phenomena showing oscillatory behavior and hysteresis A graphical method is used to illustrate how oscillation can arise in the parasite host interaction Oscillations and hysteresis are of particular importance in the behavior of the central nervous system Some simple mathematical models of these phenomena are developed for application to the behavior or the central nervous system These models are subsequently used as a basis for a discussion of some psychological effects of aging

In the sixth section physiological aging is discussed in connection with human mortality data In order to show how the entire curve may be accounted for, it is necessary to introduce immunity producing hazards as well as aging processes The former hazards are each characterized by some average time between occurrences If these average times form a progression which is more or less geometric, one obtains a simple interpretation of the early part of the mortality curve The effect of age is introduced by considering aging as decreasing various necessary functions, decreasing the tolerance to such changes, and perhaps increasing the variability in these processes By introducing a fluctuating variable, which represents a weighted average of many processes, together with a lethal threshold, it is possible to represent the principal aspects of the effect of age on mortality Combining this process with the immunity producing processes, it is possible to account quantitatively for the relationship between human mortality and age from birth to beyond 70 years

In the last section some psychological effects of aging are considered As an example, it is assumed that the only effect of age is a reduction in the numbers of neurons In terms of the model, this can be shown to result in changes in simple reaction times and recognition learning should be even more pronounced The significance of such quantitative changes is discussed in terms of the model

The models suggested in this chapter are greatly oversimplified, and the mechanisms by which age enters are far from complete However, it has been the purpose here only to illustrate how some of these processes can be formulated in mathematical terms and how, in the process, a better understanding of the underlying mechanisms may be achieved

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PART TWO

Biological Bases of Aging

IV

General Biology of Senescence

ALBERT I LANSING

I Background

Disciplined analysis or attempts at analysis of the phenomena involved in the process of growing old of the differences that exist between the young and the old and of the mechanisms associated with natural death began with the opening of the twentieth century At this time and in fairly quick succession the research activities of three men in widely dispersed areas gave rise to the field of gerontology Minot in 1908 published an excellent volume based on much of his cytological investigations In the same year Metchnikoff produced his classical treatise combining biological and medical observations with less objective speculations The eminent zoologist Child (1915) brought together the experimental data he had collected on studies of regeneration and senescence of invertebrates in a still useful volume Subsequent to this surge of activity with the exception of Pearl s (1922) beautiful monograph on the *Biology of Death* not too much occurred until the late 1930 s

Now that a definitive field of research called gerontology has come into being it is clear that communications between investigators will be facilitated if effective distinctions can be drawn between the terms aging senescence and senility

Some of the difficulties that gerontologists have been confronted with in their attempts to think together stem fairly directly from the fact that in referring to aging they may have different processes in mind To some aging refers to the process of change in the organism from the time of fertilization of the ovum until death of the individual To them the study of aging means the study of the factor of time in the life history of the organism Included in this approach is analysis of the growth and involution of specific organs in the individuals such as the thymus and uterus While this may often be what is meant by aging it is not precisely what the gerontologist is concerned with Senescence is perhaps a more specific designation for the process or processes that we often refer to as aging when we have in mind the gradual deterioration of the *adult* organism This point of view was evaluated in a symposium in 1951 which attempted to define aging (Lansing 1952*b*) I have found it convenient to define aging (senescence) as a process of unfavorable progressive change usually correlated with the passage of time becoming *apparent after maturity and terminating* invariably in death of the individual (Lansing 1951) More recently a committee evaluating the current status of research on aging came up with the following broad definition (Gerontological Society 1959) Gerontology is that branch of knowledge which is concerned with situations and changes inherent in increments of time with particular reference to post maturational stages If this point of view is sound and if we wish to be entirely clear

as to the area we are concerned with, it might be well to avoid use of the term aging and to employ more generally the specific term senescence It would follow from this that the end product of the process of senescence is the state of being aged or decrepit which is senility

II Natural Death

It would indeed be simple if clarification of terminology would suffice to clear the haze surrounding the field of gerontology Unfortunately this is not so Let us assume that we have agreed that we are concerned with the process of unfavorable change in the adult organism terminating in death of the individual How do we distinguish between the so called degenerative diseases (senescence or death due to the vicissitudes of life) and death due to endogenous changes of senescence (natural death)? Indeed can it be established that the latter occurs at all? The thinking of Robertson (1923) apropos natural death is pertinent here

> If we were to view natural death as the termination of existence due to the uniform sensescent atrophy of the organism leading to a uniform depression and ultimately simultaneous extinction of all its functions then natural death in all probability never occurs In a world in which the organism could be completely shielded from fortuitous strains and the invasive activities of parasitic organisms the phenomenon of natural death might conceivably occur In actuality death is always in some measure accidental Thus an aged individual contracts pneumonia and succumbs to its effects Death is in its immediate origin attributable in this event to the invasion of parasites which one accidentally encountered Similarly when rupture of a cerebral vessel due to arteriosclerosis occurs the existence of all parts of the body may be terminated by this accidental event but its ultimate origin is the general senescence of the tissues of which arteriosclerosis is merely one particular manifestation

The issues surrounding the concept of natural death were thoughtfully elaborated by Pearl (1922)

> The problem of natural death has two aspects one general the other special These may be stated in this way
>
> 1 Why do living things die? What is the meaning of death in the general philosophy of biology?
>
> 2 Why do living things die *when* they do? What factors determine the duration of life in general and in particular and what is the relative influence of each of these factors in producing the observed result?

Pearl enumerated several biological generalizations about natural death which are currently pertinent

(A) There is an enormous variation in the duration of life both intra and interracially [See Tables 1 and 2]

(B) There is no generally valid orderly relationship between the average duration of life of the individuals composing a species and any other broad fact now known in their life history or their structure or their physiology

(C) Natural death as distinguished from accidental death is preceded by definite structural and functional changes in the body

(D) Natural death (as distinguished from accidents) occurs normally and necessarily only in animals composed of many cells (Apropos this item modern research developments make it clear that even unicellular organisms do age and die)

In the sense that natural death is here referred to one might speculate that senescence is the process of deterioration of the adult organism leading to inevitable death of that organism Still again it might be suggested that senescence is a process involving progressive loss of the ability to live Degenerative diseases that may or may not lead to death of the individual are part of another problem They may have their origins in mechanisms quite apart from senescence or they may do their damage in a system made vulnerable by senescence Every superficial indication is that they involve mechanisms apart from that of senescence The difficulty is that although we suspect that the latter is true we are not yet in a position to establish the

fact This is inevitable, since both of the variables we are discussing exist as unknowns How can a sharp line be drawn between degenerative disease and senescence if we lack specific criteria for either?

What is the place, if any, of senescence in the scheme of living things? The most elementary presentations of the distinction between non living and living things usually list locomotion, growth, the ability to respond to stimuli, and self duplication as essential features of the living system Certainly these are valid properties of life, and it can be agreed that living things do possess these attributes However, one need not be a profound scholar to perceive that non living systems manifest some of the properties of the living—mercury is motile, crystals grow, and thixotropic gels respond to pressure The capacity for self synthesis is to all intents and purposes a distinctive property of life Quite apart from the capacity of duplication of whole organisms by reproduction and cell duplication by mitosis, there is the truly remarkable ability of protoplasm to renew itself as it is consumed by vital activities I have been perplexed and continue to be perplexed by the seeming anomaly between this self synthetic capacity of protoplasm and senescence If protoplasm is in a continual state of renewal how can it wear out?

TABLE 1

LENGTH OF LIFE OF MAMMALS AND BIRDS

Common Name	Scientific Name	Period of Gestation (Mammals) or Incubation (Birds) (in Days)	Usual Length of Life (in Years)	Maximum (in Years)
Man	*Homo sapiens*	280	70–80	110?
Chimpanzee	*Troglodytes niger*	260	15–20	> 30
Monkey	*Macacus sinicus*	160 (210)	12–14	
Cat	*Felis domestica*	56	9–10	
Lion	*F leo*	108	20–25	40
Dog	*Canis familiaris*	60	10–12	34
Bear	*Ursus maritimus (arctus)*	240	40–50	
Mouse	*Mus musculus*	21 (23)	3–3½	
Rat	*Epimys decumanus*	21	2½	
Beaver	*Castor fiber*	42	20–25	50?
Rabbit	*Lepus cuniculus*	30	5–7	
Guinea pig	*Cavia cobaia*	63	4–5	
Cow	*Bos taurus*	285	20–25	30
Sheep	*Ovis aries*	150	10–15	20
Goat	*Capra hircus*	150	12–15	19
Reindeer	*Rangifer tarandus*	240	16	
Camel	*Camelus (dromedarius)*	360–400	25–45	50
Pig	*Sus scrofa*	120	Ca 16	27
Hippopotamus	*Hippopotamus amphibius*	210–250	40	
Rhinoceros	*Rhinoceros (unicornis)*	510–550	40–45	
Horse	*Equus caballus*	330–350	40–50	62
Elephant	*Elephas indicus*	628 (615)	70	98
Fin whale	*Balaena mysticetus*	360?	Several hundred?	
Vulture	*Gyps fulvus*		118	
Eagle	*Aquila chrysaetes*		104	
Canary	*Fringilla canaria*		24	
Pigeon	*Columba livia*	17–19	50	
Chicken	*Gallus domesticus*	20–22	20	
Duck	*Anas boschas*	26–30	50	
Goose	*Anser cinereus*	28–31	80	
Ostrich	*Struthio camelus*		50	
Owl	*Bubo bubo*			68

TABLE 2

LENGTH OF LIFE OF COLD BLOODED METAZOAN ANIMALS

Group and Common Name	Scientific Name	Maximum Length of Life (in Years)*
Reptilia		
Crocodile	*Crocodilus niloticus*	40 (+?)
Alligator	*Alligator mississippiensis*	40
Lizard (skink)	*Scincus officinalis*	> 9½
Lizard	*Anguis fragilis*	>33
Giant turtle	*Testudo sumeiri*	152
Amphibia		
Toad	*Bufo (vulgaris?)*	>40
Tree frog	*Hyla arborea*	11
Giant salamander	*Megalobatrachus japonicus*	55
Salamander	*Salamandra maculosa*	11
Salamander	*Triton alpestris*	15
Salamander (axolotl)	*Amblystoma mexicanum*	12
Fish		
Herring	*Clupeus harengus*	2
Goldfish	*Cyprinus carassius auratus*	Usually 6–7, max 10
Pike	*Esox lucius*	70–80
Sturgeon	*Huso dauricus*	50–55
Catfish	*Silurus glanus*	80
Mollusca		
Snail	*Helix pomatia*	18
Marine snail	*Natica heros*	>30
Marine snail	*Littorina littorea*	20
Other snails		1, 2, 5, 10
Giant clam	*Tridacna tridacna*	100?
Oyster	*Ostrea edulis*	10
Fresh water clam	*Anodonta fluviatilis*	10
Fresh water clam	*Unio rassus*	12
Fresh water clam	*Margaritana margaratifera*	100 (150?)
Other clams		1–4
Arthropoda		
Housefly	*Musca domestica*	76 days
Fruit fly	*Drosophila melanogaster*	37 days
Bee (queen)	*Apis mellifica*	5
Ant (worker)	*Formica sanguinea*	5
Ant (female)	*F fusca*	7
Other ants		Up to 15
Beetles	*Carabus auratus* and others	7–11
Earwig	*Forficula auricularia*	5
Spider	*Atypes piceus*	7
Spider	*Mygale avicularis*	15
Lobster	*Homarus europaeus*	33
Crayfish	*Astacus fluviatilis*	30
Copepods	*Cyclops calanus, Diaptomus*	1, 1½
Annelida		
Leech	*Hirudo officinalis*	27
Earthworm	*Lumbricus terrestris*	10
Rotifera		
Rotifer	*Rotifer vulgaris*	42 days
Nematoda		
Trichina and other encapsulated parasitic worms		30
Trematoda		
Flatworm	*Planaria lorva*	1½
Polyclad	*Yungia aurantiaca*	1
Coelenterata		
Sea anemone	*Actinia equina*	>15
Sea anemone	*Sagartia troglodytes*	50?
Sea anemone	*Actinia mesembryanthemum*	66+
Hydra	*Hydra grisea*	1 (almost)
Sponge	*Axinella* sp	> 4

* Unless otherwise noted

It is this essential attribute of life that renders inappropriate the analogies between the wearing out of non living systems and the senescence of living organisms Shoes, piston rings and automobile tires wear out because of sustained friction rubber bands oxidize and become inelastic with the passage of time, and clocks run down None of these failures due to use and the passage of time is analogous to the senescence of living things The latter should, at least on a theoretical basis, contain ever vigorous protoplasm That it obviously does not can only mean that the mechanisms by self synthesis are less than perfect at least after the attainment of adulthood of the cell or organism Herein lies the crux of the problem of senescence and its inexorable sequel natural death Appreciation of the process of protoplasmic renewal and its inadequacy upon attainment of adulthood will have as its sequel an understanding of senescence

Bourne (1957) recently stated the problem in somewhat different language What mechanism is it which permits such abundant growth and cell division in the organism up to maturity and then not only brings these processes to an end but guides them into a steady and fatal decline? The biologist has little choice in his role of detective but to seek for clues in features diverse species have in common in their senescence and to attempt to correlate vital phenomena of which something is known with the phenomenon of senescence of which essentially nothing is known A chapter can be written on the various correlations that have been attempted between structural or functional characteristics and longevity For our purposes let it suffice to introduce briefly several of these for purposes of illustration

III Genetic and Other Influences

It is generally accepted and perhaps established that there is a correlation between longevity of parents and that of the progeny This can be taken to mean that a gene (or genes) determine a process (or processes) that limits the span of life, which, of course takes us back to the issues reviewed earlier regarding the maintenance of protoplasm Nevertheless the correlation does exist and is simply illustrated by data tabulated by Pearl (Table 3)

Longevity may be correlated with any number of vital characteristics, but it is difficult to judge the significance of such manipulations and still more difficult to draw any inferences Malisoff (1937) in a charmingly written volume cites data attaching particular meaning to the chrono-

TABLE 3*

Influence of a Considerable Degree of Longevity in Both Father and Mother upon the Expectation of Life of the Offspring

Father s Age at Death (in Years)	Mother s Age at Death (in Years)		
	Under 60	60 80	Over 80
Under 60	32 8 (128)†	33 4 (120)	36 3 (74)
60-80	35 8 (251)	38 0 (328)	45 0 (172)
Over 80	42 3 (131)	45 5 (206)	52 7 (184)

* From Pearl (1922) after Bell

† The first figure is the average duration of life of the offspring the figure in parentheses the number of cases upon which the average is based (From Pearl, 1922)

logical age at which adolescence is attained Thus if one takes the age at which adolescence is reached and multiplies by 13 (this factor is arrived at on an apparently arbitrary basis) a theoretical longevity may be calculated for the species concerned On this basis the rat s adolescent time of 64 days would yield a life expectancy of 3 0 years the 42 days of the mouse would yield a life span of 2 15 years and the 13–16 years of man would result in a life span of 169 208 years

TABLE 4*

CORRELATION OF CEPHALIZATION FACTORS WITH LONGEVITY

Species	Cephalization Factor	Maximal Life-Duration
Mammals		
Man	2 67 2 81	80–150 (?)
Elephant	1 24–1 34	90–100
Anthropoid apes	0 76–0 65	
Horse	0 43–0 57	45
Deer	0 40–0 50	30
Bears	0 36–0 50	50
Dogs	0 34–0 51	15 20
Cats	0 29–0 34	20
Oxen giraffes antelopes	0 30–0 40	30
Squirrels	0 16–0 20	6
Insectivora	0 06–0 18	6–10
Mice	0 04	3
Birds		
Carrion crow	0 168	100 (?)
Parrots	0 147–0 177	100 (?)
Alpine crow	0 114	50
Finch	0 086	8
Heron	0 046	15
Pheasant	0 034	15
Ostrich	0 0195	

*From Malisoff (1937)

Malisoff further discusses a speculation that the ratio of brain weight to body weight (cephalization factor) may be correlated with the maximum life span of the species The tabular data are attractive if for no other reason than that there is a peculiar virtue to be attached to mathematical calculations (Table 4)

Many of the factors that correlate with longevity are thoughtfully considered in Heilbrunn s (1943) chapter on age and death By and large there is truth in the idea that at least among mammals there is a correlation between body size and longevity Rats live longer than mice, cats live longer than rats monkeys live longer than cats etc But on close inspection of the longevity data (see Table 1), one finds serious discrepancies such as short life spans of cows horses and even elephants compared with humans Again one finds a rough correlation between length of the period of gestation of a species and its longevity The longer the period of gestation the longer the life span But, as with body size there are many notable exceptions Another interesting correlation with longevity that is frequently referred to exists in the rate of metabolism of the organism Within a class such a correlation does exist but its over all significance is still beyond us Heilbrunn (1943) points out that the mouse heart beats 520–780 times per minute and assuming a life span of 3 25 years the mouse will experience 1 110 000 000 heartbeats In contrast, the heart of the elephant beating only 25–28 times per minute will in a life span of 70 years beat a total of 1 012 000 000 times! The *remarkable similarity between these* estimated total heartbeats tempts one to attach more than coincidental significance to these observations Indeed it probably was data such as these which brought into being the suggestion that the living organism is like a clock its life span ends when the initial endowment of energy is expended just as the clock runs down when its spring is finally unwound Unfortunately for this idea we have McCay s (1952) dramatic experiments with rats which show either that there is no fixed life span endowment for the species or that the spring does not begin to run down as long as the organism is less than full grown McKay raised immature rats on a diet containing all the essential nutritional materials but lacking sufficient calories to promote growth and maturation Control rats received the same diet except that the caloric intake was adequate to enhance

growth and maturation The results were truly remarkable McCay was able to keep his immature rats in a state of immaturity for periods of 766 and 911 days but was able to reinitiate growth on these retarded animals by the simple expedient of raising the caloric intake to an adequate level These animals lived as much as 200 days longer than the controls

Still another group of experiments by Lansing (1947) on rotifers clearly indicate that life span is not determined by the biological equivalent of a clock spring These experiments will be discussed in detail in a later section At this point let it suffice to say that in rotifers reared under very careful conditions longevity of successive generations could be sharply reduced by the simple procedure of repeatedly selecting eggs from old mothers to propagate each generation This effect was completely reversible by altering the procedure and selecting eggs from adolescent mothers to establish successive generations Both McCay s and my experiments raise most fundamental questions as to the nature of the process of senescence and the biological mechanism which determines longevity Because of their implications it is essential that they be confirmed using not only the same species as in the original works but other species if possible

Mention has already been made of Pearl s (1922) early observations on an apparent genetic factor in the determination of longevity Although the data in general are not so lucid as might be desired it does seem true that the best way to assure one s self of long life is to choose long lived parents

The mathematical precision with which one can predict longevity in suitable material is illustrated in rotifers (Lansing 1947) As noted in the original work and repeated since then rotifers are particularly favorable animals for laboratory study of longevity Rotifers reproduce parthenogenetically and in many species lay eggs which yield only females at least under favorable conditions It is most simple therefore to develop large stocks of genetically homozygous animals from a single female rotifer Second rotifers are characterized by determinate development all the cells the adult rotifer is to have are laid down in the embryo As an obvious consequence there is absolute homogeneity of age of all cells in the rotifer body which eliminates a possible variable from longevity studies Third and in addition to these endogenous features rotifers can be reared under highly standardized conditions in the laboratory Temperature, composition and pH of the medium and food supply are all subject to laboratory control If one compares the life-span and fecundity of a population of rotifers (*Philodina citrina*) with those of the daughters of the same rotifers using eggs laid during the sixth day of life the data may be virtually superimposed (see Fig 1) Both populations have mean life spans of 24 0 ± 0 1 days

The bulk of the literature on inheritance of longevity has been brought together by Comfort (1956) in an excellent chapter marred only by his confusion of genetic with heritable factors in longevity The term genetic I believe is usually reserved for inheritance determined by genes while heredity may be genic or non genic (cytoplasmic inheritance maternal age influences etc)

Dublin (1949) offers a critical review of the literature concerning inheritance of longevity in the human Most of the existing data are based on geneological studies and are conditioned by the pitfalls inherent in such analysis Pearl s (1922) investigations on inheritance of human longevity already referred to rank among the most reliable Using a factor referred to as total immediate ancestral longevity (abbreviated to TIAL) Pearl extended the statistical significance of geneologic data The TIAL is based upon the sum of the life spans of the two parents and four grand parents of any individual A minimum score could scarcely be less than 90 and a maximal score would approach or slightly ex

ceed 600 (assuming 15 years as an average age of initiation of reproduction for the former and an average age at death of 100 years for the latter) In general Pearl found that marked longevity was associated with high TIAL scores

Life insurance data although useful are difficult to interpret because of the factor of selection involved in issuing policies which tends to eliminate poor risks and of misstatements of personal and ancestral histories Nevertheless extensive collections of data tend to support the existence of a hereditable component to longevity

Insofar as laboratory animals are concerned Comfort s review of the literature appears to be complete and his general conclusions are sound First longevity, from the point of view of inheritance is influenced in a negative way—by absence of genetic factors which predispose to specific fatal diseases—and second by a more nebulous quality which may be described as vigor or vitality Apropos the former, there does exist in the literature considerable data such as those of Strong (1936), indicating that specific diseases are genetically determined which are responsible for the abbreviated longevity of some strains of mice There is no known gene responsible for extension of life span while the genes which result in shortened life span do so by regulating susceptibility to diseases Senescence and the time of entrance into senility and natural death still resist genetic analysis

Comfort (1956) has an interesting discussion of hybrid vigor or heterosis This fascinating biological phenomenon has intrigued geneticists for many years The breeding of two inbred lines with limited growth size resistance longevity etc results in progeny with strikingly enhanced characteristics This is heterosis and is manifested by a wide variety of species both plant and animal The literature on this subject is extensive and is summarized by Comfort The significance of this phenomenon is still an enigma

IV Effects of Parental Age

In considering inheritance of longevity both genic and non genic it is pertinent to evaluate the influence of parental age on longevity of offspring This factor in longevity received its impetus in the work of Lansing (1947) which in turn was inspired by the observation of Jennings and Lynch (1928) that progeny of old rotifers tended to have shorter life spans than progeny of young rotifers Their data were not statistically significant but the trend was suggestive My plan of experiment combined the observation of Jennings and Lynch (1928) with the experimental design of Sonneborn s (1930) selection studies on the flatworm *Stenostomum incaudatum*

Stenostomum is a fresh water flatworm that normally reproduces by transverse fission A new individual will form by development of a new head at some point on the trunk followed by separation of this new product from the parent or anterior end The net result of such fission is that the head or anterior end possesses the old head pharynx and most of the original trunk it has only to regenerate the tail The daughter product however contains a new head pharynx and trunk and possesses but a small amount of the old caudal portion of the parent Although presumably genetically identical the two products of fission differ in that the anterior product has experienced very little new growth whereas the posterior product has undergone much active growth It is apparent that the same head will go with the anterior product of successive divisions with little or no growth while active growth with new trunks will be associated with successive divisions of posterior products

Sonneborn employed an essentially simple selection technique in the conduct of h e a

s multiplication by fission progressed two divergent lines of animals were developed by selection one type of line consisted of

successive anterior products of division and another type of line consisted of successive posterior products of division

It would be expected in an experiment such as this that in the absence of genetic nutritional or environmental variations longevity would be the same in both the anterior and the posterior lines This was not the case The mean life span for all the anterior lines was 35 days while four posterior lines that died showed a mean life span of 64 5 days Two posterior lines that were lost accidentally were observed for 77 days and two more posterior lines were carried through 115 days at which time they were discarded There seems to be a clear cut correlation in these selection studies between lack of growth and senescence and active growth and avoidance of senescence

My original intention was to determine if the statistically dubious results of Jennings and Lynch could be rendered clear cut by using Sonneborn s selection technique modified to be applicable to a sexual animal like the rotifer The rotifer as already noted is particularly suited for longevity studies It has a short life span usually extending from 1 to 4 weeks it reproduces parthenogenetically to yield homozygous stocks and it may be cultured easily in large numbers in the laboratory under highly standardized nutritive and environmental conditions so that extraneous variables are greatly minimized In addition the rotifer contains in its minute body approximately a thousand cells which make up several complex elements such as digestive excretory reproductive nervous and muscular tissues

To initiate the investigation a large number of eggs laid on a single day were isolated from a group of wild stock but homozygous mothers These eggs were allowed to hatch and were placed in isolation culture to establish the parental stock of the various series In the species illustrated the rotifers are adolescent on the second day of life reach maturity on the third day and begin to decline on the fifth day Thus to establish a line with actively growing mothers one isolates the eggs laid on the second day of life When this F_1 reaches its second day of life the eggs laid on that day are isolated to establish F_2 from adolescent mothers This procedure may be repeated indefinitely Each generation of course is placed in isolation culture and observed daily until death of the animals Each successive generation of animals with uniform parental age in each generation is termed an orthoclone

On the other hand to observe the effects of having old ancestors one isolates eggs laid on the fifth or sixth day of life of the parental stock This F_1 is isolated as before and eggs are collected on the fifth or sixth day to initiate an F_2 then an F_3 and so on All the animals are observed through their full life spans and records are maintained on fecundity and time of death

Adolescence in *Philodina citrina* is reached on the fifth day adulthood on the sixth day and obvious senility on the fourteenth to fifteenth days As the data show mean life spans in the adolescent line slowly but significantly increase over seven generations while middle aged and senile lines decline and die out over five and three generations respectively

This pattern of result was consistent through numerous different experiments using three species of rotifers Mean life span of offspring of adult or senile mothers is reduced Second generation offspring of older mothers have still shorter life-spans and so on until extinction of the line The number of generations required to reach such extinction depends upon the age of the ancestry involved

In the absence of genetic variation and environmental fluctuations and with maintenance of both internal and parallel control lines there seems no doubt but that something is transmitted through the eggs of adult or old mothers which accelerates aging in the offspring This effect is not only transmissible but cumulative Since longevity of offspring of growing mothers is increased rather than decreased it fol

lows that the aging factor either is not operative or is lacking in eggs of adolescent females

The obvious experiment at this point was to attempt to reverse the accelerated aging of late born by switching for the third generation to early born selection After two generations of senile parentage an offshoot line was established from adolescent animals while a third generation of senile parentage was also isolated The latter produced non viable eggs while the former survived and through continued selection of eggs from growing mothers showed progressive increase in longevity through three generations During the second generation an offshoot line of eggs from 8-day old (adult) mothers was started and maintained for eight generations at which time the line died out Still another offshoot line now of eggs from adolescent mothers was started in the fourth generation of the declining series and again the aging trend was reversed

From this and several similar experiments it was concluded that the acceleration of aging apparent in late born animals may be reversed This observation eliminates the possibility that we are dealing with a genic mutation Apparently, a non genic factor operates here to accelerate aging

V Growth and Aging

That there is a close association between the growth status of the individual and its aging is further supported by the following studies The previously described experiments showed that growing rotifers do not contain the aging factor while middle aged and old rotifers do contain it It also appeared that the greater the maternal age the more marked was the suppression of longevity in the offspring and hence the fewer the number of generations that were required to produce extinction of the line

Thus orthoclones of 16 and 17-day-old mothers die out in three generations orthoclones of 11 day-old mothers die out in four generations, and orthoclones of 8 day old mothers die out in eight generations At the same time it is to be recalled that ortho clones derived from adolescent (5 day-old) mothers exhibit ever increasing longevity one series was maintained through fifty four generations with a gradual increase in longevity from 24 days to as much as 104 days It is to be presumed that adolescent orthoclones survive an infinite number of generations The aging factor therefore and its limiting effect on longevity of both individuals and lines must make its appearance on either the sixth or the seventh day of life If it appears on the sixth day (when the rotifers attain adulthood) there would seem to be a direct association between growth cessation and aging

Orthoclones of Philodina citrina at 6 and 7 days were established and observed with the usual internal and parallel controls The 7 day orthoclone manifested a gradual decline in longevity through a number of generations and died out in the fifteenth generation Last and most significant the 6 day orthoclone slowly but steadily declined and became extinct in the seventeenth generation

Further evidence that growth and aging are closely linked is contained in the data on rate and time of onset of egg production Mean life span drops steadily in each descendant generation As longevity decreases there is a shift in time of onset of egg production to earlier ages and maximal rate of egg production is achieved earlier In the terminal F_4 generation egg production is much reduced and the adult rotifer is much smaller than normal

Quite the opposite occurs in a young orthoclone As longevity increases in successive generations there is a steady shift in time of onset of egg production to older ages Finally the rate of egg production is reduced and full grown rotifers are substantially larger than normal

All these observations may be summarized as follows (1) age of the mother conditions longevity of the offspring (2) the aging factor is extra genic, (3) the aging factor appears at the time of cessation of

growth, (4) accelerated aging is accompanied by accelerated growth but decreased maximal size, and (5) retarded aging is accompanied by retarded growth but increased maximal size

It was data such as these which have led me to the conviction that senescence is a phenomenon that begins at the time of maturation and hence is a problem of early maturity rather than of the period of senility The latter is significant only in that the manifestations of aging are intensified in later years, and practical issues—medical economic, and social—ensue

If we are to examine the implications of these rotifer studies insofar as survival of the species is concerned, it becomes quickly apparent that there is a potential significant difference in the continuity of young and old orthoclones Young orthoclones can be expected to survive indefinitely in keeping with the concept of immortality of the germ plasm Old orthoclones have a finite existence—in this case one cannot help but *doubt* the thesis of immortality of germ plasm The concept must be modified at least insofar as rotifers are concerned to hold that the germ plasm of adolescent individuals is potentially immortal while that of *adults has limited potentialities like* somatoplasm Although in my experiments a highly artificial selection procedure was used to produce the effects noted, it is obvious that even in nature, on a chance basis it is inevitable that some individuals will be derivatives of the equivalent of old orthoclones and some of young orthoclones Their ability to survive will be related to parental age Still further, external variables such as nutrition will influence the age at which reproduction begins as well as the rate of reproduction These variations in turn will determine whether or not the population will be rich in animals born early or late in their parents' lives The survival *of the species may well be influ*enced by this factor Needless to say, the rotifer is particularly suited for demonstration of this phenomenon, but it is possible that other species may express this potent influence of parental age to an equal or lesser extent

VI Finite Life Span

Thus far I have attempted to make the point that in the absence of the various known causes of death, such as violence and disease essentially all organisms have a finite span of life This is natural death, and it is brought about by senescence In one sense the simplest definition of senescence would be that process or groups of processes which, in the absence of external causes of death terminate life

Pearl s succinct questions quoted earlier get to the very heart of the question 'Why do living things die? Why do living things die when they do?

Despite the fact that men have thought about aging and death since they first acquired the ability to think there are surprisingly few theories of aging that are worth taking seriously This lack of speculation on the nature of senescence *in itself* is a strikingly curious phenomenon Much of biology is devoted to extolling the truly remarkable properties of living material such as the processes of self synthesis orderly *embryonic development*, cell division growth and various regulatory mechanisms Processes like these might be expected to yield a machine capable of indefinite existence, but, obviously, this is not the case These are properties of juvenile and not adult cells In this sense one might consider senescence of adult cells a biological anomaly which is amenable to mechanistic characterization Yet much of theorization in regard to senescence either has been of the "fountain of youth" variety or else has adopted the fatalistic approach

With clocklike regularity, the idea keeps coming up that aging is a result of reduction in sex endocrine function and that substitution *therapy should be effective in* postponing or reversing the effects of aging Suffice it to say that all the proponents of this concept die at quite conventional ages

Another naive theory of aging was pro

posed by Metchnikoff (1908), and it, too, has had more than one rebirth. The idea here is that toxins arising from intestinal putrefaction have a general deleterious effect upon the body and in specific cases cause aging. It is hardly necessary to point out that many organisms grow old and die which do not have large intestines in which putrefaction can occur. History tells us that Metchnikoff lived on sterile rolls and Bulgarian sour milk (rich in *Lactobacillus*) in order to alter his intestinal flora of bacteria. He died at 71.

A number of theories have evolved over a number of years based on the belief that *cellular intoxication is at the root of aging*. Jickeli proposed that cellular metabolism is an incomplete process and that, unless the cell can rid itself of deleterious metabolic by-products (by cell division or formation of insoluble structure like hair, cellulose, etc.), it will age.

Montgomery, the famous zoologist, proposed a somewhat similar concept of aging. His belief was that *excretory mechanisms* are not perfect and that, with time, metabolic waste products injurious to cells gradually accumulate and lead to death. Division again was held to eliminate, in an unspecified way, these waste products and thus lead to rejuvenation. Child, the author of an excellent though old volume on senescence, basically subscribed to this concept, as did Benedict (1915), the plant physiologist. Benedict went further to propose that waste products accumulate because cellular permeability decreases with age. This idea was still further extended by Lansing (1942), who proposed that the calcium content of cell membranes increases with age, leading to decreased cell permeability. The latter results, of course, in both diminished cell uptake and cell output.

Another group of theories center around cell organization. Minot (1908), shortly after the turn of the century, proposed that changing volume relations between the nucleus and cytoplasm (cytomorphosis) hold the key to senescence. He believed that in the young cell the volume of nuclear material with respect to the volume of cytoplasm was great but that, with advancing age and differentiation, there was a relative increase in cytoplasmic material.

That senescence is the price the organism has to pay for differentiation has been proposed by many other workers, including Delage, Jennings, and, more recently, Cowdry. Cowdry (1952) classified cells according to their ability to divide and differentiate. Thus intermitotic cells (those whose rather undifferentiated lives extend from one cell division to the next, as in the fibroblast) do not age. The other extreme is the postmitotic cell, which does age (its effective life begins with differentiation and loss of ability to multiply). Muscle and nerve cells are examples of postmitotics. The difficulty with this concept is that it is merely a restatement of the basic problem. We know that growing cells do not age while non-growing cells do; the question is: Why the difference?

The last group of theories I will outline is perhaps the most popular and with the least substance to warrant this popularity. The general idea is that aging is due to the *wearing-out of protoplasm*. Analogies are drawn between biological aging and wearing out of shoes, clocks, and automobile motors. A slightly more sophisticated version of this concept draws an analogy between protoplasmic aging and colloidal aging. Many eminent names, including Dhar, Ehrenberg, Rusicka, and Marinesco, are associated with this theory.

It is true that colloids deteriorate with age and undergo syneresis (squeezing-out of water). It is also true that the living machine does run down, simulating a worn-out mechanism. But this is as far as the analogies are apt.

The fact is that there is one fundamental difference between living cells and machines, shoes, or colloids. An essential property of protoplasm is its ability to maintain itself, to repair and to reconstitute itself. This capacity for self-synthesis sets off the living from the non-living. Protoplasm is in a perpetual state of flux, there

is a constant turnover of its constituents and replacement of individual molecules The colloids in old protoplasm are new colloids but different from those of the young, the test tube colloids are old colloids—old with respect to time The old organism does not contain old colloids, it contains *newly* formed colloids of an old character Perhaps the soundest theory of aging is that the wearing out process is due to a decrease in the cell's capacity for self synthesis

It is clear that aging is more profound than a mere problem in mammalian or human biology It is, to put it mildly, an over simplification to claim that aging is due to failure of the cardiovascular system, or digestive system, or connective tissue system The fact is that organisms grow old and die which do not possess these systems Even single cells grow old and die As Heilbrunn (1943) has clearly stated, "In the last analysis, according to any theory, senescence is due to protoplasmic changes changes which occur in individual cells "

Heilbrunn's view is readily acceptable to most, but it becomes quickly apparent that not all cells in the individual are equally differentiated, not all cells possess equal potentialities for cell division and not all cells age at the same rate Cowdry's classification of cells is now generally accepted *Fixed postmitotic* cells are those which are maximally differentiated and do not undergo cell division Nerve cells, red blood cells, and muscle cells fall in this category *Reverting postmitotic* cells are those which have differentiated and ordinarily do not divide They may, however, with proper stimulation regain the capacity for division as does the hepatic cell in regeneration of liver *Vegetative intermitotics* are those whose lives exist only between cell divisions These are poorly, if at all, differentiated and are held not to exhibit senescence *Differentiating mitotics* are closely related to the vegetative intermitotics but are their descendants and are somewhat more differentiated, like intermediate cell types in hematopoiesis To simplify our discussion, it might be well to focus some attention upon the two extremes—fixed postmitotics and intermitotics It has often been said that senescence and death are the price paid for differentiation, while cell division is an expression of a vigorous undifferentiated cell which is presumed to resist senescence

Just how true is all this? The nerve cell is a fixed postmitotic which does not undergo cell division and certainly is highly differentiated This cell in man survives in many cases for 80 90, and 100 years Certainly here it can be said that the rate of senescence must be very low, perhaps the lowest in the body On the other hand, the hepatic cell, a reverting postmitotic, which can undergo cell division on occasion, appears to fail slowly but steadily with advancing age With maturation of hepatic cells, one finds an increase of binucleate cells, followed later by inhibited cytoplasmic and karyoplasmic growth but with normal chromosomal multiplication yielding polyploid cells Indeed, some studies indicate that the ability of cells to grow by increase in volume or number decreases with age (Minot 1908 Needham, 1949) Along similar lines there is evidence that the re

1950) Mitotic activity decreases with age in mouse liver (Bullough, 1946), but after partial hepatectomy hepatic cells can be stimulated to divide (Bucher and Glinos, 1950)

The whole question of the roles of differentiation and cell division in senescence is a difficult one with little clear evidence to support any hypothesis Why do highly differentiated cells like neurons age so slowly in the absence of cell division? Yet why and how does cell division restore vigor to declining cells? Is cell division an attempt on the part of the cell to rid itself of debilitating agents? Is cell division an expression then, of a declining cell rather than a vigorous one? These are questions that only further study can elucidate

Characterization of the senescence of in

dividuals and populations of individuals is just as difficult as attempts at characterization of individual cells Unt l ...

... of us certainly recognizes that the ... is a phen ... is qu ... and ... u viuual who does not have too much longer to live The picture is clear —we have no difficulty in understanding

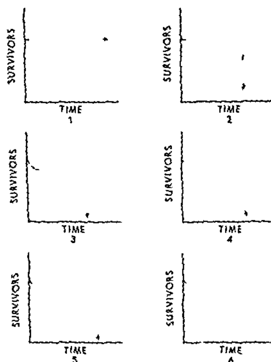


FIG 1 —Hypothet cal survival curves for a vari ety of populations and factors influenc ng morb d ty (See text for details)

one another when we deal in such generalities The situation is much more difficult when we attempt an objective definition of aging There are no established criteria of aging at the histological biochemical or physiological levels that permit a solid definition The enfeeblement of the old man may be and usually is traceable to degenerative diseases such as arthritis cardiovascular disease cancer etc Even death of the old man is most generally attributable to a specific clinical situation such as pneumonia cardiovascular disease or respiratory failure It is the rare individual who comes to autopsy at an advanced age and reveals no recognizable cause of death Is the latter the rare case of death from old age?

VII MORTALITY OF POPULATIONS

The statistical approach helps to make this point clear Let us examine the survival curve of a population of rotifers *Drosophila Daphnia* mice rats or men—the pattern is remarkably the same in all species The survival curve in its simplest form merely plots the percentage of survivors in a population as a function of time It is typically a sigmoid curve starting with 100 per cent at zero time or birth and falling off until the last survivor has perished (Fig 1 *6*) The very shape of this curve indicates clearly that at least several factors ordinarily operate to kill off the population at various ages Obviously if chance operated uniformly at all ages to decimate a constantly vulnerable or fragile population the survival curve would be a straight line—this is not the case

Mortality is a characteristic of the vast majority of species and these may exhibit variations in the shape of the survival curve but all sooner or later reach a zero survival of the population Were this not the case we would find a population which in the absence of infant mortality violent deaths and diseases would yield a survival curve consisting of a straight line running parallel to the abscissa at the 100 per cent level (Fig 1 *1*) This is a highly hypothetical situation that undoubtedly has never occurred in nature

If we were to assume a population in which no factors other than senescence were operating a population which was genetically homozygous exposed to a standardized environment and nutrition we would expect to find a rectangular survival curve (Fig 1 2) in which the population would have died off quite simultaneously at

an appropriate age for the natural death of that population This situation too un doubtedly has not occurred in nature but the fewer lethal variables there are in a population and the more standardized the population is the closer its survival curve will approach this rectangular shape

Various factors do operate to decimate a population Very early in life one must reckon with deaths due to congenital de fects and with the susceptibility of the in fant to a variety of diseases Our ideal sur vival curve must be modified accordingly to allow for the infant mortality which reduces the population from its original 100 per cent level (Fig 1 *3*) In the adolescent and young adult population infections vio lence and predation operate further to re duce the population the degree of damage done to any group by factors such as these varies with the species Even in the so called civilized species of man these factors atten uate the number of survivors as a function of time after birth We must then further modify our survival curve to include a variable number of deaths in the young population (Fig 1, *4*)

This is not the end of attrition in our population The middle aged and elderly organisms are susceptible to a variety of lethal diseases which in man are referred to as degenerative diseases ' Without taking into account generally existing vari ables like genetic constitution nutrition and environmental stresses the survivors in the mature population are further re duced in a variable way lending further curvature to the pattern of the survival curve (Fig 1 *5*)

Now we find that we have constructed the major part of a typical survival curve less the unusually long lived few that carry on long after their fellows are dead The factors that are responsible for the longev ity of this small percentage of the popula tion may be inferred to include heredity nutrition environmental variables and chance

There is finally a significant point to be made In the best regulated populations under laboratory conditions the most that we have been able to do is to increase the rectangularity of the survival curve Early deaths as with rotifers can be eliminated from the population since late in life most of the animals die over a very short period of time approximating what was sketched in Figure 2 The point is very fundamental and bears on the question Is there such a thing as death because of old age (natural death)? Is it true that if we could eliminate infant mortality violent deaths and degen erative diseases we would wind up with a population exhibiting indefinite longevity? I doubt if we can give an unqualified an swer to these questions with the information now on hand Yet the fact that refinements in a population accentuate the rectangular ity of the survival curve would seem to imply that the phenomena of senescence and natural death do exist

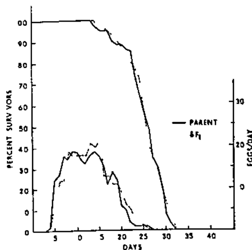


FIG 2 —Life span and egg laying of *Philodina citrina* (rotifera) over six generations in normal cul ture (Lansing 1952*b*)

Thus far in our discussion we have dealt largely with what is popularly referred to as problem identification Since very few objective data on the properties of senes cence and senility are on hand the problem is essentially unidentified But as is the case whenever data are few it is very easy

for all to hypothesize and philosophize When it comes to experimentation on senescence, the situation is quite different Only a few approaches are available to us, we can make measurements to determine how old organisms differ quantitatively or qualitatively from young organisms As a matter of expediency we usually contrast the very old with the very young Second, we can attempt to influence the rate of senescence by introducing variables such as nutrition and temperature The hope in experiments such as these is to gain an insight into the dynamics of the processes involved Third we can attempt to reverse the changes of senescence or senility with the laudable objective of restoration of youth Thus far attempts along these lines have been to put it generously lacking in scientific substance Fourth we can attempt to extend our understanding of the phenomenon of senescence by analysis of situations which mimic this process A good example of this approach can be found in progeria a relatively rare disease of children which at least superficially reproduces some of the characteristics of an aged person Baldness and wrinkling are usually present, and the victims of the disease typically die at roughly 8 years of age because of coronary artery disease Whether or not progeria truly mimics senility remains to be determined but, regardless of the outcome, close scrutiny of this disease is indicated

VIII Radiation Injury and Aging

In recent years there has been increasingly frequent reference to the possibility that radiations may induce changes which mimic those of senescence Again while it remains to be determined whether or not this is so the working hypothesis warrants careful analysis There is no question but that, should a quantitable variable like radiation induce the same changes as those of senescence, research in the latter would be greatly expedited

Much of the pertinent literature on this subject has been brought together in a recent review by Upton (1957), to which the reader is referred The essential argument involved is that ionizing radiation shortens life span and that the degree of shortening is proportional to the amount of such radiation This observation alone justifies attempts at analysis of a possible mimicry of senescence by ionizing radiations It should be kept in mind, however, that the shortening of life span alone is not an absolute measure of senescence and that many factors other than senescence may accom [illegible]

real problem is to determine whether or not *specific* features of senescence are reproduced by radiation, and here we are very much handicapped How can we equate radiation effects against senescent changes when we have no significant data on the identity or properties of senescent changes? This to me, is the crux of the problem but it does not mean that attempts at analysis of the working hypothesis will be fruitless

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V

Morphology of the Aging Nervous System

WILLIAM BONDAREFF

I Introduction

In presenting the morphological aspects of the aging nervous system, an attempt has been made to present a useful point of departure to the reader wishing to pursue the subject in greater detail and hence no complete review of the literature is intended We have been shown much but taught very little about aging and this review purposes to present the current status of cellular aging in the nervous system in such a manner that certain limitations in our knowledge will be known From the vast literature of observations has been sorted out that which is illustrative of past trends pertinent to present understanding or indicative of promise This literature is presented not as a catalogue of unrelated events but as relevant to functional cytology for the relation of cellular structure (especially fine structure) and physiology is the essence of cytology

The literature of neuropathology has contributed a major portion of current gerontological knowledge It has therefore, seemed advisable to begin this presentation with a consideration of human neuropathology both macroscopic and microscopic As this material is presented it will be related to data of later sections concerning general neurocytology

Since much of the earlier literature concerned with neuronal aging has derived from the study of human autopsy material a variety of limitations has been imparted to the morphological data obtained For example the number of aged specimens which can be utilized may be restricted by the general inaccessibility of human cadavers Also since sudden, traumatic death not the resultant of chronic disease is relatively uncommon among accessible cadavers the number of ' normal control specimens is usually insufficient Other limitations often dictated by the use of human material are perhaps obvious and include the often unavoidable introduction of artifact due to the investigator's inability to control the length of the post mortem period or to choose a satisfactory fixative or method of fixation

A large part of the neuropathological literature concerned with gerontology is therefore difficult to interpret in terms of biological aging It has, nevertheless, appeared advisable to present and discuss at least certain aspects of this earlier literature since it forms much of the foundation upon which we attempt to develop an experimental science of gerontology Having discussed the gerontological data of neuropathology and their various implications, data concerning more directly the neuron and its subcellular elements will be examined

II Human Neuropathology

Macroscopic Anatomy

A detailed description of the gross and histological alterations of the human senile nervous system more properly belongs in a

textbook of neuropathology (see Braunmuhl 1957) and the subject will be only briefly dealt with here as background information for the student of the cytology of aging Most of these changes appear to belong to the literature of pathology rather than that of normal biology and it would be almost impossible to select rationally those alterations which merit emphasis as phenomena of aging For a discussion contrasting normal aging and pathology consult Lansing (1952) There is nevertheless a fairly voluminous literature dealing with morphological alterations of the human nervous system which are found with greater frequency in the aged than in the young Such a literature must depend upon the study of autopsy specimens in which morphological preservation is often poor This is especially relevant to the study of microscopic anatomy and should always be considered when attempting to evaluate data In many cases it has not been possible to know with certainty whether an observed phenomenon has resulted from faulty preparative technique a degenerative disease of the aged agony or so-called normal aging Yet it would seem advisable to discuss briefly some of the morphological alterations which have been associated with normal old age and to differentiate them from the better known atrophies with definable clinical manifestations While considering these alterations the reader is cautioned to bear in mind that there will be a percentage of any elderly population which at autopsy exhibits an apparently normal (i e youthful) neuroanatomy

Brain weight and volume —If in a large population brain weight or volume is determined and plotted as a function of age it may be readily seen that a decrement occurs with increasing age (Fig 1) The mean brain weight varies widely within each age group and appears to be maximal between ages twenty and thirty Though the random error is high brain weight appears to fall at a uniform rate with age the greatest relative decrease being about 11 per cent between 25 and 96 years (Appel and Appel 1942) Perhaps more frequently than any other gross anatomical change a decrease in brain weight and size is noted in old individuals although the literature concerning these phenomena is often misleading and must be approached with considerable caution

In the first place the definition brain is not a standard one and there is considerable difference in weight depending upon where the brain is severed from the spinal cord and upon the manner in which the investigator chooses to deal with the meninges and cerebral spinal fluid (Bailey and Bonin 1951) One might assume however that were one investigator responsible

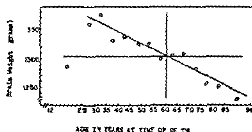


FIG 1 —Regression of brain weight with age at time of death For ages 25–96 inclusive the mean weight of the brain is 1305 44 grams (*horizontal line*) the mean age at death is 60 29 years (*vertical line*) (Redrawn from Appel and Appel 1942)

for removing the brain, these factors would be standardized and the error uniform throughout an age series though there may be little basis for such an assumption Second and perhaps more influential there is considerable variability depending upon the length of the post mortem period preceding the removal of the brain and the temperature at which cadavers are stored during this time According to Appel and Appel (1942) both the mean and the median weights of the brain gradually increase for many hours after death and probably for more than 6 days (Fig 2) This increase may amount to about 9 per cent is influenced by various pathologies and at least in part seems to be due to the absorption of cerebral spinal fluid The cause of death has also been shown to in

fluence the brain weight (Appel and Appel, 1942) which was found relatively high in subjects whose death resulted from suicide or sudden accident On the other hand certain pathologies namely arteriosclerosis and cancer are reported to be associated with a relatively low mean brain weight Thus with such data there is also an age bias and a decrement of weight or volume appearing a priori to be age dependent which may be more directly related to the post mortem interval or temperature the cause of death or a somatic pathology

It has also been thought that brain weight can be associated with intellectual ability and the attempt has been made to

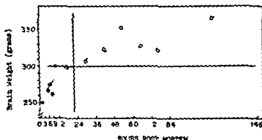


Fig 2 —Variation of brain weight with the numbers of hours post mortem for 1544 cases (Redrawn from Appel and Appel 1942)

associate the characteristically decreased brain weight of the senium with the decreased mental ability that may accompany advanced age The opinion that intellect is associated with brain weight is however to be seriously doubted The brain of Anatole France for example was found by Tilney (1928) to weigh only 1017 grams which has been said to suggest a primitive condition In antithesis to this Stevenson (1958) has reported that of the many brains examined by him one from a 7 year-old idiot and another from a 6 year-old afflicted with gargoylism weighed the most—1970 and 1550 grams respectively That a decrement in the brain weight of an individual may be associated with intellectual capacity is another matter entirely unknown

Loss of brain weight has been repeatedly reported as an age-associated event and recently Himwich (1958) reported that the 1394 gram average which is maximum for males drops in individuals of 90 years to 1161 grams Brain weights for women are lower but a similar course is observed Himwich attempted to account for this decrease in total weight and his data indicate that it is due more to a decrease in total brain proteins and lipids than to water but the actual role of water in accounting for these results is not yet understood It would seem that though there may be an increment in brain water in the senium (Burger 1956) there is a decrease in intracellular water (see p 167)

Associated with the decrement in brain weight a decrease in brain volume relative to the capacity of the skull has been reported This leads to the shrunken appearance which is often described as a concomitant of advanced age Generally, the method by which this has been determined has been that of Reichardt (1905), in which the volume of the cranium is determined and considered the potential volume of the brain mass The observed difference between these two then, is expressed as a percentage of the potential volume and is normally between 9 and 11 per cent (Grunthal 1936 Hoff and Sietelberger, 1957)[1] A weight differential of 11 17 per cent indicative of atrophy seems to be characteristic of the brains of men

[1] In the case of a brain weight of 1365 grams and a skull capacity of 1504 cc a "differential weight" is calculated as follows (see Dohmen 1941)

$$\frac{\text{Brain weight in grams (including arachnoid and pia)} \times 100}{\text{Skull volume in cubic centimeters (without dura)}} = \frac{1365}{1504} = 90\ 75 \text{ per cent}$$

of the skull occupied by brain Thus the weight differential (100 per cent — 90 75 per cent) is 9 2 per cent

who possessed no obvious psychological disturbances in their ninth decade, and a weight differential of 24 per cent has been reported in cases of Alzheimer's presenile dementia (Morel and Wildi, 1952)

Gross brain structure —A shrunken aged brain will often exhibit an exaggerated pattern of cerebral cortical convolutions where the gyri are narrow and the sulci wider and deeper than normal (Fig 3) This is chiomian bodies which are local enlargements of the arachnoid villi, may be hypertrophied the corpus callosum atrophied (also observed in Alzheimer s disease), and the basal ganglia may appear shrunken The latter is especially true in cases of Alzheimer s disease where there may also be atrophic signs in the mesencephalon and substantia nigra It might be added that in neither so called senile degeneration, Alzheimer s disease nor Pick s disease is atherosclerosis a necessary concomitant Also those few studies that have been made in the attempt to associate metabolic events with the neuropathology have not proved fruitful (Morel and Wildi 1952)

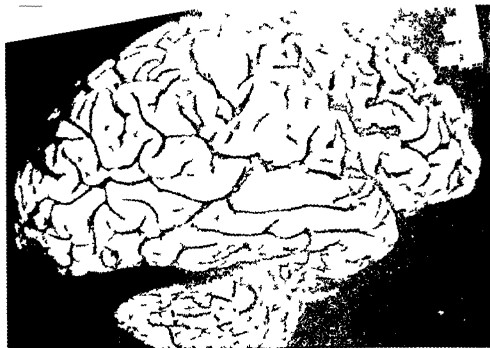


Fig 3 —Atrophic senile brain. Characteristically the most severe atrophy is observed in the frontal region (After Dublin 1954 courtesy of Charles C Thomas Springfield)

usually more prominent in the frontal lobes (Grinker and Bucy 1949) but in Alzheimer's disease it is diffuse and marked not only in the frontal but also in the temporal and parietal lobes In Pick's disease (lobar sclerosis), which most commonly involves the frontal and temporal lobe cortex there is an extensive though circumscribed, atrophy Associated with such senile degenerations are various other gross indications of atrophy, such as abnormalities of the meninges, which may show various degrees of thickening The pac

Autopsy of the brain of an individual afflicted with Pick s disease will often reveal a grossly distorted extended ventricular system This is especially true of the lateral ventricles where the anterior horns may be so distended with fluid as to obliterate a large proportion of the parenchyma. Senile

degenerations in general will also exhibit, to one degree or another, extended ventricles, especially the lateral ventricles (Fig 4) Morel and Wildi (1952) have determined the volume of water that can be injected into the ventricles of formalin fixed brains of an elderly group of subjects and have reported that the ventricles in both men and women dilate progressively during life Then after about age 80 in the case of men and about 85 in that of women the ventricles not only cease to increase but decrease rather markedly These phenomena may be associated with a thinning of the ventricular tissue (Grinker and

MICROSCOPIC ANATOMY

That there are alterations of the microscopic structure of the aged brain is, of course redundant but it is quite a different matter to associate unequivocally the gross with specific histological events The gross morphological findings are not well correlated with age the clinically diagnosed mental disturbance, the duration of the disturbance or the histological lesions observed in brains from aged persons This has been realized for some time and remains a timely problem of neuropathology, perhaps the result of the preparative methods normally used in pathological studies

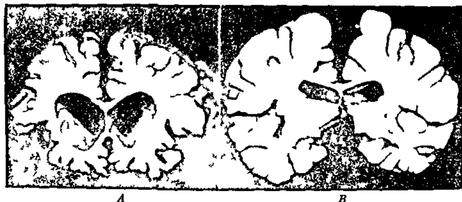


FIG 4 —Marked enlargement of lateral ventricles *A* cross-section through frontal lobes *B* cross section through temporal region (After Dublin 1954 courtesy of Charles C Thomas Springfield)

Bucy 1949) and with a compensatory increase of the cerebral spinal fluid resulting from the decreased brain volume (Himwich 1958) The roentgenological investigations of Heinrich (1941) which were *performed on living human subjects*, corroborate these observations of increased ventricular volume

Unfortunately, no systematic study of this nature has yet been performed on laboratory animals The great apparently preferential involvement of the lateral ventricles would indicate the influence of certain local factors but the process by which the ventricles actually increase in volume and the significance of this to the aging process, as well as to the physiology of the organism, are not understood

However as there are grossly demonstratable changes in the brain with increased age there must also be microscopic ones and these will be discussed

Such histological changes as have been *described range from slight differences* in the staining of basic proteins on the one hand to pycnosis on the other In many discussions of these changes there seems to be a tendency to provide description with a directional order In the German literature one may find order imposed by classification, which while usually not expressed often appears to be implicit in the American literature Such would seem to be an unfortunate practice, for the reader is left with the misconception that there is a known sequence of aging which proceeds in

a directional manner with barely detectable phenomena on one end and cell death on the other the majority of the described morphological alterations falling between these two extremes Thus far there have been few data in support of this concept and for the most part the available data indicate that it is not valid

Neuronal distribution —Perhaps one of the most common findings in the microscopic study of the aged nervous system is a decrease in total number of cells It has been often reported that the neuron density in various parts of the brain declines with age The literature dealing with this particular observation however, will not be thoroughly reviewed here for much of the older work is difficult to evaluate owing mainly to uncertainties regarding the methods of sampling and counting employed It is known for example that improper fixation post mortem autolysis and rough handling prior to fixation can cause an apparent decrement in cell count (Cox 1936)

In a recent study Brody (1955) has counted nerve cells in four parts of the cerebral cortices of twenty human subjects who died from non nervous disorders and were brought to autopsy 1–4 hours post mortem The greatest decrease in the neuronal population is reported to occur in the superior temporal gyrus and the least in the postcentral gyrus The precentral gyrus area striata and inferior temporal gyrus showed intermediate degrees of cell loss Critchley (1942) has also reported a decrease in nerve cells in the human cerebral cortex most marked in the frontal cortex but also found in the basal ganglia thalamus subthalamic area cerebellum and brain stem According to Critchley (1942) this was primarily an involvement of the pyramidal cells of the third cortical lamina

The largest number of studies dealing with cell counts have concerned the cerebellar cortex which lends itself well to such studies owing to the linear arrangement of Purkinje cells A decrement in Purkinje cells of human brains has been reported to amount to about 25 per cent (Hodge, 1894 Ellis 1920 Harms 1944), and there is some slight indication that this loss is greatest in the anterior lobe of the cerebellum (Ellis 1920)

In the eighth and ninth thoracic spinal ganglia a decline of about one third of the total number of cells has been reported (Gardner 1940) A 32 per cent decrement in the numbers of dorsal and ventral root fibers from these same two thoracic spinal nerves has been reported by Corbin and Gardner (1937) who attribute this to a loss in spinal ganglion nerve cells It should be noted however that the latter study was based on one case of an 89 year old male and a count of fibers in well fixed rat sciatic nerve demonstrated no age difference (Birren and Wall 1956)

General neurohistology —Other than the numerical decrease in neurons cellular and tissue changes have been described as correlates of the aging process in the human brain Necessarily all these descriptions have been based on autopsy material taken from the very limited and selected popula
[illegible] hospitals and with notably

cases It has been demonstrated that brain weight can be influenced by the post mortem time elapsing before removal of the brain (Appel and Appel 1942) and with the temperature at which cadavers are stored during this period (Bailey and Bonin 1951) These factors are seldom considered by investigators concerned with the morphological examination of the human brain It is also reported that brain weight can be influenced by various non nervous pathologies and routinely such material comprises the control group of neuropathological investigations or the so called normal old age group in studies of age changes Lastly a relationship has even been established between brain volume and prevailing socioeconomic situation (Todd 1927) It would seem probable that such conditions which can affect the gross characteristics of the human brain would

also affect the microscopic structure and most likely to an even greater extent It would therefore be extremely difficult if not impossible to classify the microscopic changes into a rational sequence except perhaps on the basis of frequency or relative obviousness Therefore it will suffice for the purpose of this discussion to simply state that microscopic examination of the brains from old individuals more often than not presents a morphology differing from that of young or healthy adult individuals Whether or not these changes actually depend upon a basic aging process is not known their heterogeneity would seem to indicate that their relation to aging is not a direct one

The descriptive gerontological literature of microscopic neuropathology might then be classified on the basis of ease of detection obviousness or stated in terms of pathology severity of the histological lesion Such a classification might include (1) an apparently normal microscopic anatomy revealing no detectable histological lesion (2) alterations of the histological structure exhibiting various degrees of subtlety and (3) a blatantly altered histolog cal structure characterized by severe grossly disruptive lesions Such changes will be briefly discussed omitting for the present changes involving the various specific parts and organelles of the nerve cell which will be discussed later under the head ng of the particular component involved

1 *Apparently normal microscopic structure*—Perhaps as common a finding as any of the myriad of described neuronal lesions is the occurrence of unaltered cells or groups of cells (nuclei) It is for that matter not uncommon in a histological examination of the brain from an aged subject to find relatively large areas where the appearance of the parenchyma is completely normal The underlying mechanisms of such find ngs are not known but they could as easily depend upon the vagaries of histological procedure as upon individual physiological differences in the neurons

Were nuclei to be examined with some morphologically specific method it would not be unusual to find that not every cell of an afflicted nucleus was affected For example when Sudan black is employed to stain the senility pigment lipofuscin one often finds pigment free cells and those containing pigment in great abundance in the same microscopic field It should also be realized that the visualization of many morphological changes depends upon the use of specific methods of fixation and staining and that more often than not a method designed to bring out the subtleties of for example nuclear structure fails to demonstrate other cellular structures

The histophysiological interaction between nerve cells and their extracellular environment which might be of paramount importance in regard to this discussion represents a relatively unexplored and almost totally unknown facet of neuroanatomy Localized regional differences such as appear to occur in connective tissue ground substance (Bondareff 1957*c*) might be anticipated in the extracellular ground substance of the nervous system Such differences and for that matter those of the connective tissue accompanying blood vessels might be expected to affect profoundly the vascularization and thereby the metabolism of individual cells or groups of cells

A better understanding of these phenomena would be of great interest especially in view of the currently held theory that each nucleus of the nervous system enjoys its own evolutionary process (Vogt and Vogt 1946) According to this concept the specific physical and chemical characteristics of the cells establishes a specific vulnerability different for d fferent types of nerve cells

2 *Mildly altered microscopic structure*—At one time or another largely dependent upon the variety of preparative method then being employed neuropathologists have described morphological changes in aged human brains involving almost every known component of the nerve cell Nor

mally depending upon the specific part of the nervous system examined nerve cells have characteristic shapes and sizes In human brains which as has been mentioned are usually rather poorly fixed shrinkage is a common occurrence and may lead to variformed nerve cells The separation of fact and artifact with regard to such changes as a function of age would appear almost entirely impossible Yet such changes have been described (see Andrew 1956*a* 1956*b*) a few of which will be mentioned here

In the cerebellum shrunken Purkinje cells have been found and associated with aging (Ellis 1920) Hopker (1951) who was concerned with the large cerebellar nucleus dentatus *found shrinkage in the* large cells of the nucleus after the seventieth year but he considered this not related to the aging process In areas 4 17 and 24 of the cerebral cortex where pyramidal granular and spindle shaped cells are respectively found Riese (1946) has observed some cell shrinkage in old brains but does not find this to correlate with a subject s age Opposed to the rather common occurrence of shrunken cells in the aged nervous system Kuntz (1938) reports finding hydrotrophic enlargement of cell bodies in autonomic ganglia

Another observation is of interest here chiefly because of its uniqueness In the human amygdaloid nucleus the cells of the ventral nuclear mass tend to form conglomerations composed of three or four cells surrounded by an extracellular material which can be differentiated from the main mass of extracellular substance It has been reported by Sanides (1957) that in two brains from humans aged 86 and 100 the material connecting these cells tended to disintegrate and the conglomerate was thus dispersed

Atrophic cytoplasmic changes of a general nature *are all inclusive*—hyalinization vacuolization fatty degeneration hypo and hyperchromidia etc The significance of most of these changes when considered in terms of the methods used in their demonstration is extremely doubtful That they are related to age gross changes or each other is also doubtful And since they have been enumerated and described by other reviewers only a few will be discussed here

In the nucleus basalis which is composed of large and small neurons and lies ventral to the putamen and pallidum a rather remarkable degenerative change has been found localized in the large cells (Buttlar Brentano 1954) This change which is termed grobwabige Zellveranderung is a fatty degeneration and as the name indicates is characterized by a gross honeycombed appearance of the cytoplasm It is not restricted to old brains but can occur *in young stages and its significance if any* to aging is not known In another study (Sanides 1957) of the deep ventral nucleus of the amygdaloid a rather mild deposition (as compared to the other amygdaloid nuclei) of lipofuscin was accompanied by the appearance of fat and vacuoles in the cytoplasm Unfortunately the latter study was concerned with so few specimens in each age group that a conclusion as to the significance of these events to aging is difficult to derive

Other morphological observations which belong to this grouping will be presented later when the individual cell components are discussed

3 *Severely altered microscopic structure* —The intensification of those changes described under paragraph 2 above leads to lesions of varying degree of severity that are readily recognized in histological sections It would seem most probable that the majority of microscopic events which belong to this grouping are at most only indirectly related to aging and most probably are the result of a host of possible pathological insults Such lesions are characterized by the presence of cells which have all but lost their identity and have assumed grossly distorted forms Such events would comprise for example the almost total displacement of cytoplasm by lipofuscin pigment cell pycnosis severe

fatty degeneration, or the gross fibrillary change of senile and presenile dementia

Senile dementia and presenile dementia (Alzheimer s disease) which do not appear to be differentiated clinically are characterized at autopsy by gross morphological alterations which are similar in the two disturbances There is a marked atrophy especially of the frontal lobes and in Alzheimer s disease the temporal lobes and as a rule the parietal lobes as well are involved (Sjorgren *et al* 1952) The brain is small and markedly reduced in weight and, in one case, atrophy of the corpus callosum (Sjorgren *et al*, 1952) There is, of course, marked loss of cortical neurons

Microscopic findings are similar in both senile and presenile dementias, and there does not seem to be any constant correlation between severity of symptoms and lesions (Dublin, 1954) This is, however, a point of contention, for Grinker and Bucey (1949) conclude that the number of senile plaques of which more will be said later, correlate with clinical severity in Alzheimer s disease (see also Grunthal, 1930)



FIG 5 —Series of ganglion cells prepared by silver impregnation to demonstrate the characteristic neurofibrillar picture of Alzheimer s disease (After Braunmuhl 1957 courtesy of Springer Verlag Heidelberg)

and presents a wrinkled shrunken appearance (Grinker and Bucey 1949) The pia arachnoid is thickened, gray and opaque and the dura tends to be dense and fissured (Dublin 1954) According to Dublin (1954) arteriosclerosis is present only coincidentally and Sjorgren *et al* (1952) report little atherosclerosis of the basalar artery Gross study reveals pathologies which though similar to those previously described for the senile brain, tend to be more severe Interesting additional findings not generally noted, are loss of neurons in the basal ganglia resulting in a cribiform appearance, which may also be found in the mesencephalon and substantia nigra,

Neurofibrillar changes—Characteristic configurations so-called Alzheimer's cells (Fig 5) are found though their occurrence is not limited to presenile dementia Although it has apparently not been possible to correlate the presence of Alzheimer s cells with any metabolic disorders (Morel and Wildi 1952), they are said to also occur in cases of senile dementia, familial spastic paralysis, encephalitic Parkinsonism, Tay Sachs disease, disseminated sclerosis, amyotrophic lateral sclerosis, scarlet fever–caused mental deficiency, and experimental rabies (Stevenson, 1958) According to Alexander and Looney (1938*a*), neurofibrillar changes are found in a great

many other diseases of the central nervous system as well as in death by starvation and exposure to cold (Donnaggio 1906) and during hibernation in lizards (Tello 1904) A similar change could be produced by soaking fresh human brain in water or various sodium chloride solutions prior to fixation (Alexander and Looney, 1938*b*) Alzheimer s cells occur especially among small pyramidal cells of the outer cortical laminae and according to Dublin (1954) are most prevalent in the hippocampus next the frontal cortex and to a much less extent in the more deeply lying cortical masses Rothschild (1937) found Alzheimer s cells in all but two of twenty four cases of senile psychosis ranging in age from 66 to 100 years and believed them to be most common in Sommer's sector of the cornu Ammonis and neighboring parts of the hippocampal gyrus Apparently Alzheimer s cells first appear in Ammon s horn and only much later in the isocortex (Morel and Wildi 1952 Hoff and Sietelberger 1957)

The genesis development and composition of these highly argentophil configurations is not understood nor is their in vivo significance which will be discussed later However they are generally considered in conventional neuropathology as having originated from neurofibrils which become coarsened with age According to Hermann (1952) by the age of 80 years the neurofibrils of cardiac sympathetic ganglion neurons are coarsened in almost all cases In the nodose ganglion coarsening was found in most of the large cells after the seventh year The cause of this coarsening is not understood and considered in terms of conventional neuropathology at least two possible explanations exist (1) that a specific physical chemical alteration in the fibrils themselves is responsible and (2) that the phenomenon depends upon the deposition of some as yet unidentified argentophil substance on or between the individual fibrils That this may be amyloid has been suggested by Divry (1952) who found these altered cells characterized by several of the histochemical reactions believed to be indicative of amyloid That lipofuscin may be responsible has been suggested by Sosa (1952)

Microincineration studies of Alexander and Meyerson (1936 also see Alexander and Loone 1938*b*) indicate that a change has occurred in the neurofibrils or in the neuronal cytoplasm which as a result of fixation and silver staining appears as neurofibrils Unlike unaffected neurons the neurofibrillar structure of Alzheimer s cell is characterized by deposits of mineral ash after incineration which may contain calcium oxide (Alexander and Looney 1938*b*)

Senile plaques —Senile plaques (Fig 6) also characteristic of presenile and senile dementia occur regularly but are not absolutely associated with the occurrence of Alzheimer s cells (Rothschild 1937) Apparently they can be found in cases where there is no clinical evidence of dementia and can be absent in cases where there is (Sjovall 1932) In his study Rothschild reported plaques common in the putamen and caudate nucleus and in all but one case none was observed in the globus pallidus More recently Dublin (1954) has stated that plaques occur most often in the hippocampus next the frontal cortex while in the insula and other cortical areas they occur much less frequently They are infrequently found in the cerebellum and brain stem and never in the spinal cord According to Hoff and Sietelberger (1957) senile plagues are preferentially found in areas susceptible to circulatory disorders

cur in the absence of vascular impairment

Senile plaques are variously formed argyrophilic structures occurring in the gray matter Their usual form is a circumscribed platelike formation with a central more or less homogeneous core around which appears a reticular corona (Fig 6*B*) In such formations the core may be non argyrophilic (Alexander and Looney,

1938b) The plaques may also be more granular or filamentous and appear as circumscribed or diffuse deposits, in which case they comprise what Divry (1952) has termed ' substance trichosique " A noticeable glial reaction apparently involving astrocytes and oligodendroglia (Dublin 1954) usually surrounds the plaque

As in the case of Alzheimer's cells, the origin and composition of the senile plaques are not understood It is generally thought that the altered processes of neurons or glial cells enter into the formation of plaques, and not uncommonly the necrotic remains of a nerve cell is found within the plaque It has also been suggested by the

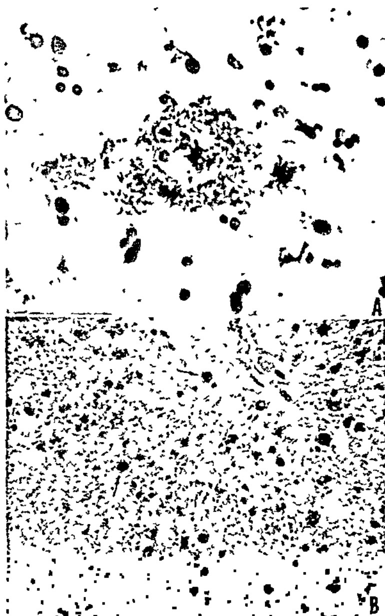


FIG 6 —Senile plaques characteristic of presenile and senile dementia *A*, low magnification photomicrograph of human cerebral cortex *B*, photo micrograph illustrating platelike structure of plaque (Courtesy of Dr W H McMenemey)

work of Braunmuhl (1932) that the plaques result from the precipitation of inorganic products formed by localized physiochemical alterations of the extracellular ground substance and only secondarily cause a glial reaction. This view, however, is not compatible with the findings of Alexander and Myerson (1936) who observed no increased mineral ash at the sites of plaques in microincinerated sections and suggested that an altered glial reticulum was responsible.

Senile plaques have been found to be metachromatic to toluidine blue, double refractive, iodophilic, and to give a positive reaction with Congo red. It has been said, therefore, that they contain amyloid (Hoff and Sietelberger, 1957). They may also contain acid phosphatase (Morel and Wildi, 1952), especially in newly formed plaques. Schiffer (1957) has found that senile plaques react positively with the periodic acid Schiff reaction and that a localized increase in periodic acid Schiff staining of the extracellular reticulum is their initial appearance.

Another grossly disruptive and rather rare pathology, more frequently observed in women than in men and associated with the senium, is Pick's disease or lobar sclerosis, which can be clinically differentiated from the presenile and senile dementias (Sjorgren *et al.*, 1952). A very severe cortical atrophy of frontal and temporal lobes is found, and Bonfiglio (1952) reports additional involvement of the basal ganglia, especially the nucleus caudatum and putamen, and also the anterior and dorsomedial nuclei of the thalamus. Whether degeneration of the basal ganglia is primarily or secondarily due to degeneration of the prefrontal cortex (Simma, as cited by Bonfiglio, 1952) is disputed. According to Dublin (1954), the anterior and interior parts of the temporal lobes are most severely affected and then the frontal lobes, especially the frontal poles and anterior thirds. Senile plaques and Alzheimer's cells found in the above mentioned dementias are not found in Pick's disease, but peculiar, enlarged cells, "balloon cells," are found throughout the cortex (Sjorgren *et al.*, 1952).

III. General Neurocytology

LIPOFUSCIN

Cytology of lipofuscin.—Of all the neurocytological events that have been correlated with aging, the accumulation of intracellular pigment, lipofuscin, is perhaps one of the most reliable. By this it is not meant to suggest that the accumulation of lipofuscin is directly related to the process of aging but only that in certain nerve cells an increase in pigment is a characteristic concomitant of advanced age and that in these cells at least the relative amount of intracellular pigment is generally a fairly reliable index of chronological age. However, as the recent studies of Sulkin (1958) have shown, increased chronological age is not the only phenomenon to be correlated with increased pigmentation. Various experimental conditions which probably have as their common denominator the induction of a state of relative anoxia have been shown to increase the amount of lipofuscin in neurons. Such conditions include the subjection of an experimental animal to an atmosphere of low oxygen content, the feeding of acetanilid, and probably the administration of a vitamin E–deficient diet, which also causes an increase in intracellular pigmentation, also belongs to this category.

Lipofuscin pigment is readily observed in nerve cells after a variety of histological procedures (Figs. 7 and 8), and its morphology is relatively unaffected by conditions such as post mortem autolysis. It occurs in certain neurons of both animals and humans and has been the object of much study and speculation. Whereas lipofuscin occurs in at least some cells of various nuclei throughout the nervous system, it is to be emphasized that not all nuclei are necessarily involved, and, of those that are, the occurrence of neurons apparently free of

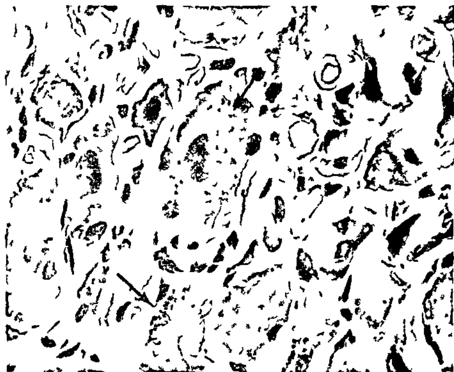


Fig 7 —Sp nal gangl on neurons from a 24 month old Sprague Da ley rat f xed by freez ng and dry ng and sta ned with Sudan black B to demonstrate l pofusc n (*arrows*) ×1250



Fig 8 —Spinal gangl on neurons from a 24 month-old Sprague-Da ley rat fixed by immers on in buf fered osm um tetrox de Lipofuscin ind cated by arrows ×1380

lipofuscin is not uncommon. Why lipofuscin pigment should be so distributed is an interesting question to which there are several possible explanations.

In the opinion of the group headed by C. and O. Vogt (Institut fur Hirnforschung und allgemeine Biologie, Neustadt) the sequence of morphological, age-associated changes are characteristically different for each cell type (Vogt and Vogt, 1946), and a specific course of intracellular pigmentation is characteristic of different nuclei. This latter thesis has been developed by Wahren (1957), who finds the onset and intracellular distribution of pigment different in the pallidum, the nucleus tuberomammilaris, and the nucleus tuberolateralis of the hypothalamus. According to Wahren, the large cells of the pallidum are practically free of lipofuscin in the first three decades, and only after the age of 70 years do they uniformly contain pigment. In the nucleus tuberomammilaris, lipofuscin begins to appear in the large cells in the fourth decade and predominate after the age of 60 years, although lipofuscin free cells may still be found in the sixth decade. In the medium sized cells of the nucleus tuberolateralis no pigment is found up to the third decade, but, by the fifth decade, lipofuscin containing cells predominate, and thereafter no cells free of lipofuscin are found. In these three cell types Wahren has described different intracellular distributions of the pigment. Buttlar-Brentano (1954) has studied the nucleus basalis and reports lipofuscin to be found at the poles of cells from normal mature subjects. Apparently, as aging progresses the lipofuscin breaks up, and its intracellular quantity becomes greatly increased. In the hypothalamus no lipofuscin pigment was found in the supraoptic or paraventricular nuclei. The course of lipofuscin has also been found to be different in three nuclei of the amygdaloid complex by Sanides (1957), who unfortunately studied only one specimen in various age groups. In the deep medial nucleus no pigment was found in a 12 year old, some cells contained pigment at 24 years and at 40 years pigment was found in all cells. Pigmentation was much less severe in the lateral and ventral nuclei. In the former pigment first appeared at 40 years, was still mild at 58 and at 100 years cells were all but filled with lipofuscin. In the ventral nucleus only a few of the large cells contained pigment at age 58. Similar data concerned with the large pyramidal cells of the cerebral cortex (Balthasar, 1954) and the nucleus dentatus (Hopker, 1951) further indicate that the specific course of pigmentation observed in various neurons is dependent upon specific characteristics of the neuron which determine a cell—or cell group—specific aging process.

Another possible explanation as to why lipofuscin is variously distributed may be concerned with specific vascular differences. On the basis of Sulkin's (1958) experiments it may be possible to generalize that anoxia of any origin will tend to increase the amount of lipofuscin in neurons and thus the condition of the vascular tree may have a significant influence on the deposition of lipofuscin. Were this the case, one might argue, on the basis of what is known of the role which connective tissue ground [illegible] have a dominant role in pigment genesis.

The sequence of events whereby pigment is formed and accumulated in nerve cells is not well known, yet, at least in certain cells, the accumulation of lipofuscin proceeds at a steady rate throughout the life span. In human sympathetic and vagal ganglia the progressive involvement of cells has been reported to be 7 per cent first decade, 8–14 per cent, second decade, 18 per cent, third decade, 25 per cent, fourth decade, and 30–33 per cent, the highest value reached, during the fifth decade (Hermann, 1952). It cannot, however, be said that the pigment material is chemically the same at the various stages of the process, indeed, there is evidence that it is not (Pearse, 1953). Very few studies have attempted to deal with this problem, one of which is

Hopker s (1951) study of the nucleus den tatus Like the olivary nuclei and pallidum the dentate exhibits pigmentation quite early and as many as 10 per cent of the cells may be pigmented by the sixth year According to Hopker (1951) lipofuscin formation begins in the so called lipophilic center of the cell generally located near the nucleus and five formative stages may be recognized (1) fine spherical particles are found diffusely distributed in the lipophilic center (2) lipofuscin formation still dif fuse extends to the border of the Nissl substance (3) the particles begin to ag glomerate and the lipofuscin which for merly could be distinguished only by its double refraction now assumes a yellowish color which gradually deepens (4) as the process continues the cytoplasm is re tracted toward the nucleus so that the cell is almost delimited by lipofuscin on the op posite side and (5) finally what once was a cell is represented by an agglomeration of lipofuscin which may also be vacuolated

In an excellent review of aging Matz dorff (1948) describes a similar course of pigment deposition although in more gen eral terms and differing from the preceding chiefly in that no lipophilic center is recog nized According to Matzdorff (1948) the process begins with the appearance of fine lipid particles diffusely distributed through out the cytoplasm These then increase in size darken and clump the latter differing with the cell type and producing the vari ously formed pigment depositions In its completed form the pigment may be scat tered throughout the cytoplasm concen trated at one pole or as in Purkinje cells be entirely lacking The latter observation however is doubtful for whereas lipofus cin is not abundant in human Purkinje cells it is infrequently observed (Andrew 1956*a*) and occurs regularly in the Sprague Dawley rat (Bondareff unpub lished) and mouse (Fullmer personal com munication) (Fig 9) Accord ng to Matz dorff (1948) the different cellular condi



FIG 9—Lipofuscin p gment (*arrows*) in mouse Purkinje cells peracetic acid aldehyde fuchsin Halm preparation follo ing neutral formal n fixation (Courtesy of Dr Harold Fullmer see Fullmer 1958)

tions apparently stem from cell specific variations in the mechanism whereby agglomeration occurs and not to more basic differences in a ' lipophilic center '

A more precise correlation of the genesis of lipofuscin with some specific portion of the cell has been attempted but the attempt has thus far not been too rewarding Matzdorff (1948 p 32), who believes the cytoplasmic ground substance to be implicated in pigment genesis has treated the problem as follows

> The matrix of lipofuscin is protein (Bethe and Fluck 1937) and on it are bound a lipoid substance and a yellow pigment Concerning the origin of these substances in the course of cellular aging the lipofuscin represents a dispersed phase of the plasma colloid which tends to decrease in its dispersion and finally to flocculate (Sjovall 1932) This however does not completely explain the origin of lipofuscin for in addition to the precipitation of an already existing substance there is often an increment in the pigment portion of the lipofuscin

Matzdorff s opinions are based on the writings of Braunmuhl (1932) and Sjovall (1932) and seem to agree with the more recently expressed opinion of Wunscher (1957) The aging of cells is considered similar to that of colloid solutions in which following a decrease in the water rich phase there occurs a concentration or precipitation of existing materials (synaresis) Thus far this hypothesis has not been adequately tested

In addition to the cytoplasmic matrix mitochondria the Golgi apparatus and also the cell nucleus have been associated with the origin of lipofuscin pigment The latter view offered by Hertwig (cited by Dolley 1917) and by Dolley (1917) is impossible to defend and today is only of historical interest According to this idea (Dolley 1917) aging represents a state of cellular exhaustion whereby the chromatin is depleted As this process proceeds the nucleolus is deprived of its nucleolar-associated chromatin and becomes brown (in toluidine blue preparations) and the chromatin (specifically, the karyosome or chromatin clumps occurring on the linin network) is transformed into pigment

More recently the concept has been developed that lipofuscin pigment may be of mitochondrial origin The work of Payne (1952) has been quoted as being indicative of this view (Hess 1955) but the evidence is only indirect and not at all conclusive Working with the White Leghorn chicken Payne (1952) has reported mitochondrial changes in certain of the endocrine glands of old cocks In the peripheral cortical cells of the adrenal gland the first sign of aging noticed in mitochondria was a loss in the capacity of mitochondria to stain with acid fuchsin At this stage the mitochondria according to Payne appear as pigment like bodies which is not to say that mitochondria are pigment and is perhaps an unfortunate simile Indeed further stages of this process as described by Payne would tend to indicate that at more advanced ages such brown pigment like bodies are no longer seen whereas swollen, vacuolated mitochondria are

A mitochondrial origin of lipofuscin pigment has been further indicated by electron microscope studies of spinal ganglion neurons of old rats (Fig 10) When ultra thin sections of osmium fixed spinal ganglion are viewed in the electron microscope, electron dense osmiophilic pigment particles are readily observed in close morphological association with cytoplasmic vacuoles (Hess 1955 Bondareff 1957*a*) These vacuoles have been interpreted by Hess (1955) as mitochondria which have become swollen and vacuolated and closely resemble the degenerate mitochondria described in the mouse anterior pituitary (Weiss and Lansing 1953) The formation of pigment is believed to begin in intimate relation with the swollen mitochondria in which the borders become dense and the cristae mitochondrialis disappear A precise mechanism as to how the swollen mitochondria actually transform into pigment particles however is not provided by Hess (1955)

On the basis of electron micrographs it

is difficult to determine accurately the nature of the cytoplasmic vacuoles found in association with pigment but there are several reasons for not interpreting them as mitochondria

In the first place the pigment associated vacuole is limited by a single clearly defined membrane and not the double membrane characteristic of mitochondria Secondly this single membrane is usually found to be intact between the pigment and the vacuole If the mitochondria were to vaculate and the vacuoles coalesce to form pigment (as these seem to imply) one would expect pigment inside the vacuole membrane Such does not seem to be the case [Bondareff 1957*a* p 367]

The pigment associated vacuoles may well be non mitochondrial and the origin of lipofuscin from degenerate mitochondria still does not seem likely however the actual relation between pigment and mitochondria is not known The following possibilities might be noted (1) the relation between pigment and mitochondria may be one of spatial contiguity or (2) the relation may be similar to that described by Palade and Schidlowsky (1958) relative to lipid inclusions in pancreatic and hepatic cells and suggestive of a functional association

It has also been observed (Bondareff 1957*a*) that the pigment vacuole configurations discussed above resemble in many ways the Golgi complex described by Dalton and Felix (1956) Submicroscopic vesicles and membranes are often associated with the peripheries of the vacuoles and the dimensions of these vesicles as well as those of the vacuoles are similar to those described by Dalton and Felix (1956) for morphologically similar components of the Golgi complex Bondareff (1957*a*) has sug



FIG 10 —Electron micrograph of spinal ganglion neuron from a Sprague Dawley rat age 24 months fixed by immersion in buffered osmium tetroxide *Lipofuscin indicated by arrows* (After Bondareff 1957*a*) ×3775

gested the following interpretation of the electron micrographs (1) the walls of the vesicles and vacuoles of the Golgi complex thicken, (2) the vesicles gradually become particulate, and (3) the particulates coalesce forming the larger particulate pigment complexes

The relation of lipofuscin to the functional integrity of the cell containing it is uncertain, there being an overabundance of speculation and a predisposing paucity of controlled experimentation A brief but adequate discussion of this matter is provided by Matzdorff (1948) Predominant in earlier literature is the notion that lipofuscin is detrimental to cells containing it, but more recent authors tend toward the opinion that lipofuscin is an inert slag product of no particular metabolic importance (see Hydén and Lindstrom, 1950, Hopker, 1951)

Generally overlooked in the gerontological literature, the tissue culture study of Murray and Stout (1947) may have a bearing on this problem When cultured, human sympathetic ganglion cells were observed to contain a variable amount of pigment (Fig 11), which in the course of 2 or 3 weeks could change from transparent yellow brown to opaque blackish brown Cells containing the latter never migrated, and frequently their nuclei lost their staining properties while those containing a large number of light brown pigment granules would migrate only short distances It would seem from this study that pigment may be detrimental to normal function either by virtue of its being a rigid mass interfering with the plasticity of the cell (Murray and Stout, 1947) or for other reasons not known

Chemistry of lipofuscin—The chemical constitution of lipofuscin is still poorly understood primarily because of technical difficulties encountered in its analysis Histochemical methods are not, as a general rule, sufficiently specific, and biochemical analysis must be hampered by the difficulty in making a positive identification of the pigment in homogenates Also, since pigment is generally stained by chemically non specific methods and on the basis of these is defined as lipofuscin, there is reason to believe that many chemically diverse substances are known as lipofuscin, and one cannot, a priori, equate the lipofuscin of one organ with that of another

The most comprehensive biochemical analysis of lipofuscin that has come to the attention of this reviewer is that of Heidenreich and Siebert (1955), who have isolated and analyzed lipofuscin from the cardiac muscle of old human subjects It is perhaps unfortunate for the purposes of this review that these authors were not concerned with the lipofuscin from human brain, but the isolation of a lipoid pigment from whole brain homogenates would be technically quite difficult, and the presence of melanin pigment in human brain would further compound the difficulty However, the method of Heidenreich and Siebert (1955) will be presented for it could apparently be adapted to the study of neuronal lipofuscin as well as those pigments from other organs which histologically appear closely related to lipofuscin In addition, it may be of interest to compare these biochemical observations with those derived from histochemical analysis

Briefly, the isolation procedure is to ho-

fuscin containing fraction is allowed to settle out spontaneously in a cylinder containing two different concentrations of sucrose After further centrifugation and washing in distilled water, a black brown pigment is obtained which may then be dried When smears of this material are prepared, certain staining reactions are obtained which parallel those obtained in sections of nervous tissue staining with fat stains such as Sudan III and Scarlet R, staining with Nile blue sulfate, and staining with neutral red In addition, the pigment granules possessed a yellowish brown color, were highly refractive, were fluorescent (the fluorescent spectrum having a wave length between 480 and 570 mμ, with a maximum of 525 mμ),

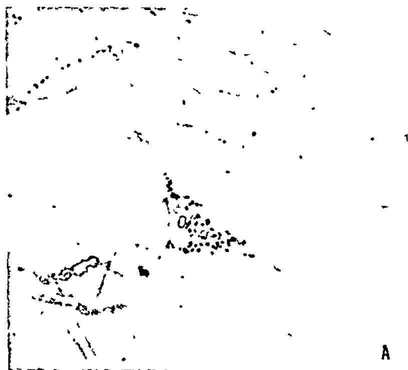




Fig 11 —Neurons from human sympathetic ganglia in vitro *A*, 2 weeks in vitro impregnated with osmium tetroxide ×600 *B*, living ganglion cell, 2 weeks in vitro stained with neutral red ×450 (After Murray and Stout, 1957, courtesy of Dr M R Murray)

and were found not to be acid fast with the Ziehl Neelsen carbolfuchsin procedure

It appears that Heidenreich and Siebert *(1955) have in fact isolated lipofuscin* but the relation this bears to the lipofuscin of brain is unknown, and whether the isolated lipofuscin has been altered from its intra cellular condition due to the isolation pro cedure cannot be answered The results ob tained from chemical analysis of this pig ment are presented in Table 1

The histochemical characteristics of lipo fuscin which follow, unless specifically stated otherwise refer to that granular pig ment which is found abundantly in certain neurons of aged vertebrates That there may be intermediate stages in the histogen esis of lipofuscin where all or some of these

TABLE 1*

CHEMICAL PROPERTIES OF CARDIAC LIPOFUSCIN

ORGANIC CONSTITUENTS		ENZYMATIC CONSTITUENTS	
Protein	11 8 per cent N content (Kjeldahl) for lipofuscin; 14 7 per cent N content fat free residue	Cathepsin	Activity about ten times smaller than that of pan creas (hemoglobin sub-strate)
Fat	20 per cent dry weight	Non specific	
Amino Acids	Most amino acids charac teristic of protein (pa per chromatography with case n as standard)	Esterases	Activity several hundred t mes smaller than that of hog kidney or rat liver (phenolphthalein sub strate)

INORGANIC CONSTITUENTS

Element	Inorganic Constituents in Lipofuscin (Per Cent)	Inorganic Constituents in Heart Muscle (Per Cent	Method of Determination
Mg	0 1 1 0	0 056–0 135	
Si	0 1 1 0	0 005–0 013	
Ca	0 03–0 3	0 018–0 068	
Al	0 01–0 1	0 000225	
Cu	0 001–0 01		
Fe	0 01–0 1	0 0029–0 0072	Steinheil quartz spec trograph (Mg to Ni)
Mn	0 0001–0 001	Trace	
Zn	<0 1	0 0033	
Sn	<0 05	0 00535	
Cr	<0 03		
Co	<0 001		
Ni	<0 001		
S	Strong qualitative reaction		Na Nitroprusside reac tion after sodium re action
P	0 42	0 51 1 06	Photometrically after ashing

PHYSICAL PROPERTIES

Birefringence	Negative
Fluorescence	Faint yellow brown intrinsic fluorescence 4800 A 5700 A max at 5250 A (not necessarily indicative of nucleotides)
UV Absorption	2200 A–3600 A max at 2720 A

STAINING REACTIONS

Neutral red	+	Ehrlich reaction	−
Nile blue sulphate	+	Biuret	
Acid fast (carbol fuchsin)	−	Sudan III and scarlet red	+
Haemotoxylin	blue green	Ninhydrin	+

* Source Heidenreich and Siebert (1955)

characteristics are not applicable is recognized and in this regard reference is made to Pearse (1953, p 361), who believes that during an initial stage lipid precursors are formed and that, as these gradually undergo oxidation the physical and chemical properties of the pigment change The comments of Lison (1953 p 454) are applicable

> Nous avons parlé de lipofuscines au pluriel car il est visible que tous les pigments designés sous ce nom ne sont pas identiques De façon genérale les lipofuscines de couleur claire, jaune clair à jaune paille se colorent mieux par les colorants liposolubles noircissent mieux par OsO_4 donnent une teinte noir franc par la méthode de SMITH DIETRICH tandis que les varietes foncées jaune brun à brun se comportent de façon opposee Il nous paraît vraisemblable que ces varietés puraaient n être que des stades d une même evolution mais nous avouons qu il n en existe pas de preuves positives

The capacity of the intracytoplasmic granules of lipofuscin to stain with various oil soluble dyes in general, depends upon the preferential solubility of the dye in the pigment as compared to its solubility in the solvent in which it is applied Thus lipofuscin is stained black when treated with a saturated solution of Sudan black B in 70 per cent alcohol a characteristic of unsaturated fatty acids (Fig 7) Also indicative of fatty acids though chemically not specific, lipofuscin blackens when treated with aqueous solutions of osmium tetroxide (Fig 8) or silver nitrate and stains with iodine

Lipofuscin may be stained with basic dyes such as Nile blue sulfate According to Lillie (1956), the staining reaction depends upon one of two mechanisms (1) below pH 1 0, staining, as in the case of the Sudan dyes, depends upon fat solubility, and the dye is readily extracted by acetone or alcohol, (2) above pH 3 0, staining occurs by an acid base mechanism, and the greenish color that results is not decolorized by acetone or alcohol extraction On the basis of these reactions Lillie (1956) has developed a method whereby staining is accomplished by treating tissue sections with a 0 05 per cent solution of Nile blue A in 1 per cent H_2SO_4, and decolorization does not result from subsequent extraction with alcohol or acetone By this method lipofuscin may be differentiated from melanin which is decolorized by alcohol or acetone extraction

The ability of lipofuscin promptly to reduce ferric ferricyanide mixtures to Prussian blue formed the staining method introduced by Schmorl (1928) and is an excellent empirical method for the demonstration of lipofuscin The chemical significance of this reaction, however, is not well known It is probably a reaction of polyunsaturated fats and may be due to the presence of fatty acid peroxides rather than to ethylenic groups per se Ceroid pigment from the liver, which appears to be a polymerized unsaturated fat (Lillie, 1952), gives only a faint or negative reaction The Schmorl reaction is identical to that developed by Chevremont and Frederic (1943) for the demonstratiön of sulfhydryl compounds, but that the reaction does not, in the case of lipofuscin, depend upon the availability of $-SH$ groups may be indicated by the absence of these groups in the lipofuscin isolated from heart muscle

It has been reported that lipofuscin is acid fast, but the property of acid fastness is not yet interpretable Acid fastness refers to the ability of certain substances to stain with basic dyes such as fuchsin or crystal violet and not to be decolorized by subsequent treatment with acid alcohol Ceroid pigment from human liver possesses this property, but the reaction is dye dependent occurring with carbolfuchsin but not with crystal violet (Berg, 1953) After formalin fixation lipofuscin in neurons of old dogs and humans (D'Angelo *et al*, 1956) is acid fast to carbolfuchsin (Sulkin, 1955), but this property was not found in rat nervous tissue after fixation by freezing and drying (Bondareff, unpublished)

The periodic acid–Schiff reaction and the closely related peracetic acid– and performic acid–Schiff reactions are known to give relatively specific and reproducible re-

sults when properly employed and have found wide application in histochemistry These techniques and their appropriate controls have been applied to the study of ceroid pigment by Lillie (1952) whose results indicate the presence of both ethylenic and 1,2 glycol groups Unfortunately the application of these techniques to the study of lipofuscin has not been sufficiently thorough to permit as critical an analysis as in the case of ceroid Sulkin (1955) however has shown that lipofuscin (old dog) gives a positive Schiff reaction after prior oxidation with periodic performic and peracetic acids and that the periodic *acid reaction is blocked by prior acetylation* That lipofuscin is closely related to ceroid as Sulkin concludes is probably accurate though it is not entirely justified Lipofuscin from old human brain (D Angelo *et al*, 1956, Brody 1957) gives a positive periodic acid Schiff reaction and that from old rats and mice has been shown to give a positive peracetic acid–Schiff reaction (Fullmer, personal communication) In the latter case it was shown that fixation in hot chloroform methanol abolishes the reaction implicating again the lipoidal moiety of the pigment It has been thought for many years (Hueck 1912) that lipofuscin pigment consists of a lipid and a protein portion though no wholly satisfactory explanation of the morphological relationship of the two parts has yet been offered According to Bethe and Fluck (1937) intracellular lipofuscin exists as a proteinaceous particle on which are bound the two substances (i e lipid and yellow pigment) which give the pigment its name

Histochemical methods for the intracellular localization of enzymes have been applied to the lipofuscin problem by Gedigk and Bontke (1956) These methods depend upon local enzymatic action to split a suitable substrate and the subsequent demonstration of a resulting substrate product at the site of enzymatic action With both the acid phosphatase method of Gomori (1941) which depends upon the deposition of lead phosphate at the site of enzyme action and the azo dye method of Grogg and Pearse (1952) the hydrolytic enzyme acid phosphatase has been demonstrated to be associated with lipofuscin granules in neurons of old human spinal ganglia The presence of non specific esterase which splits the esters of the higher as well as those of the lower fatty acids has also been detected at this same site Gedigk and Bontke (1956) concluded that the lipofuscin granules had a strong affinity neither for the hydrolytic enzymes (in the surrounding cytoplasm) nor for the substrate or reaction product of the incubation mixture They believe that both acid phosphatase and *non specific esterase are actually associated* with the pigment

A brief discussion of certain physical data will conclude this discussion of the chemistry of lipofuscin The physical data presented have been taken from the work of Hyden and Lindstrom (1950), who investigated anterior horn cells from the cervical enlargements of human spinal cords

Absorption spectra (Fig 12) were taken in both the ultraviolet and the visible parts of the spectrum and absorption maxima were found at 2600 A 2800 A and 3750 A The possibility that the 2600 A and 3750 A maxima indicated a flavin could be discluded by subsequent tests. The 2600 A band which was found not to disappear after digestion with ribonuclease and the 2800 A band are indicative of organic nitrogenous bases and protein substances and were found in areas of the cell which corresponded to those occupied by pigment The pigment showed a yellowish fluorescence when excited which was found to contain two moderately strong bands between 4400–4600 A and between 5300 A and 5600 A The fluorescence and absorption data were taken to be indicative of the presence of pterins which in solution have been shown to possess similar fluorescence maxima

The absorption of filtered X radiation ($\lambda = 8$ A) which is proportional to the total amount of substance per surface unit in the histological section [?] indicated that

the cellular areas containing pigment have about 50 per cent more dry substance than their surroundings This datum was compared to that obtained by the microincineration of sections which showed a higher density of ash in the pigment containing areas The microincineration experiment of Hyden and Lindstrom was performed at 500° C for 1 hour and the resulting sections were studied in dark field

Recent unpublished studies (Bondareff) have shown that when performed at 500° C for 1 hour microincineration is incomplete (rat spinal and cervical sympathetic ganglia) and the ash of pigment containing sites when viewed in bright field appears black This would indicate the presence of carbon and the absence of minerals at these sites It is interesting to note that more carbon appeared in pigment from sections fixed by freezing and drying than in those fixed by the usual alcohol formalin mixture The only conclusion which appears to be justifiable from this and the X ray absorption data of Hyden and Lindstrom (1950) is that lipofuscin pigment is denser (i e contains more dry substance per surface unit sections) than the surrounding cytoplasm

GOLGI COMPLEX

Almost 50 years ago Camilo Golgi described a reticular structure in spinal gan

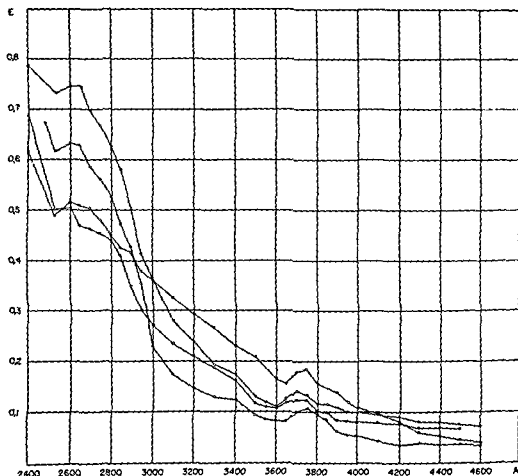


FIG 12 —Absorption spectra of the yellow pigment in anterior horn cells from a man 50 years old (After Hydén and Lindström 1950, courtesy of Dr Hydén)

glion neurons and since that time the relation of the so called Golgi apparatus to the living cell has remained a highly controversial subject It does not seem appropriate to enter into the controversy here but age associated changes of the Golgi apparatus have been described and it would appear appropriate that they be briefly mentioned in this review As one might expect there is little agreement with what these morphological changes are and still less with what if anything they mean to aging

Andrew (1939) has compared the Golgi apparatus in Purkinje cells of the mouse at various ages and found considerable uniformity within each age group In young mice the Golgi apparatus occurred as a well formed classical reticular structure closely associated with the nucleus Contrarily the condition of the Golgi apparatus in old mice (698 733 days) was characterized by the presence of a large number of argentophil granules irregularly distributed throughout the cytoplasm

There is considerable literature from the laboratory of J Bronte Gatenby also indicating that the Golgi substance undergoes fragmentation in the neurons of old animals Very generally this group of investigators interprets the Golgi substance as a filamentous canalicular reticulum According to Gatenby (1953) the reticulum in old m ce tends to loosen from its normal position around the nucleus and fragment forming small densely argentophilic particles A similar situation is reported in the spinal ganglion neurons of old rabbits (Gatenby and Moussa 1950) and in the spinal cord and spinal ganglion neurons of old amphibians (Moussa and Banhawy 1954) Moussa (1952) working with spinal ganglion neurons of the toad *Bufo regularis* found that as the toad ages the Golgi canals break up so as to form spheroidal bod es which could be stained with Sudan black and were more concentrated toward the periphery of the cell Under the same conditions the non fragmented Golgi reticulum did not stain with this dye The observations indicating either that the fragmented bits of the Golgi substance are transformed into pigment or that the pigment is a secretion product of the Golgi substance have been discussed above

Contrary to what is maintained by Gatenby Baker and his colleagues believe that the Golgi substance does not occur as a filamentous reticulum but as spheroidal bodies which in general possess the same staining properties (Baker 1944) These spheroidal bodies or Golgi elements have been said to undergo change with age Malhatra (1957) has described such bodies in the neurons of the frog and has reported that in the adult *Rana tigrina* both homogeneous and duplex spheroids are found The latter form consists of an outer pellicle around an inner core and are more numerous in old than in young animals With increasing age according to Malhatra (1957) the spheroids increase in size and lose their pellicles Their position in old frogs at one pole of the neuron is reported to differ from that of young animals where they tend to be juxtanuclear and as already mentioned they appear to be associated with the origin of pigment

Relative to the confusion that clouds the Golgi substance the apparent general agreement that at least its morphology changes with age would appear a rather unusual and interesting observation Of course one can only speculate as to what these morphological changes signify with regard to aging and in this regard reference is made to the work of Bourne (1950) and of Sulkin and Kuntz (1952)

Other indications that the Golgi apparatus may be involved in pigment genesis derive from the studies of Gatenby and his co workers who have described a fragmenting of the reticular Golgi apparatus in various old animals In old rabbits (Gatenby and Moussa 1950) the Golgi apparatus of sympathetic ganglion cells has been observed to fragment into highly argentophyle pieces some of which appeared to form pigment The relation of these pigment granules to lipofuscin

clear for apparently they are not sudano philic In a later publication (Gatenby and Moussa 1951) a lumbar autonomic ganglion from a man 60 years of age was examined and sudanophilic granules described The mechanism of pigment derivation as expressed in this later publication differs somewhat from that described previously Pigment granules were seen in close morphological association with the Golgi canals on which they were believed to originate The granules were thought to detach from the canals and migrate through the cytoplasm to the axon hillock In the opinion of Gatenby and Moussa (1951) these pigment granules are or contain a hormone or similar substance representing part at least of the neurosecretion of the nervous system although the evidence in support of this opinion is largely lacking A similar conclusion was reached by Gatenby (1953) from a study of mouse sympathetic ganglion studied with the phase-contrast microscope

In lower vertebrates the situation appears somewhat more confusing because of uncertainties about the morphology of the Golgi apparatus Moussa (1952) who has studied the Golgi apparatus of *Bufo regularis* described a canalicular reticulum and a mechanism of pigment genesis comparable to that described by Gatenby and Moussa (1951) The conclusion expressed by Moussa and Banhawy (1954), based upon their study of frog and toad neurons seemed to be in line with that of Gatenby and Moussa (1950) However in a study of the neurons of *Rana tigrina* Malhatra (1957) failed to find a reticular Golgi apparatus at all but in agreement with Thomas (1948) he found variously formed spheroidal bodies which appeared homologous with the Golgi element described by Baker (1944) These spheroids are both homogeneous and duplex that is they appeared as a chromophobe core contained in a chromophil pellicle and especially the duplex type is reported to increase with age The core of these spheroidal bodies forms a pale yellow material which increases with age and would appear to represent the pigment described by other authors

MITOCHONDRIA

An extensive biochemical literature indicates the essential role played by mitochondria in the physiology of cells A cytological expression of this role is seen for example in the classical experiment performed in the laboratory of R R Bensley (Ma 1928) in which it was shown that when guinea pigs are starved the mitochondria all but vanish from the acinar cells of the pancreas A priori one might expect that if aging does occur in nerve cells its course could be read in the mitochondria

Recently in preliminary experiments Weinbach and Garbus (personal communication) have found liver mitochondria from old Sprague Dawley rats less stable than those from young rats when subjected to various deleterious environments Such environments can be induced for example by in vitro storage and thermal insult Weinbach and Garbus find that if the P^{32} ATP exchange reaction is determined with freshly prepared mitochondrial fractions no differences between young and old mitochondria can be observed If however this reaction is determined after in vitro storage of the isolated mitochondria the greater susceptibility of the old mitochondria to extraneous insult is evident Although there are intrinsic difficulties in applying the methodology for isolating liver mitochondria to nervous tissue preliminary experiments by Weinbach and Garbus (1956 1959) with brain mitochondria have shown no age associated decline in oxidative phosphorylation when succinate is used as substrate Nor is a decline in the P^{3} ATP exchange reaction observed

In what would thus appear a promising area in which to approach the cytology of aging cytological studies are surprisingly

the number of mitochondria decreased and eventually disappeared Later, in the endocrine glands of fowl Payne found that mitochondria were markedly changed in certain glands from old animals. According to Payne (1952), mitochondria became transformed into variously shaped bodies which increased in size and fused Such alterations in mitochondrial structure were noted in the basophils and acidophils of the anterior pituitary, in the follicular cells of the thyroid and in certain cells of the adrenal gland In the anterior pituitary of Rhode Island Red cocks, Payne (1946) observed that the number of basophils steadily increased from 10 days after hatching to the onset of sexual maturity and that in old animals the basophil count as well as pituitary function declined At what age the peak in basophil count occurs was not known but according to Payne there may be a 50 per cent decrement in functional basophils at ages from 6 to 9 years

The electron microscope study of Weiss and Lansing (1953) is in general in agreement with these results In all three cells of the anterior pituitary swelling and an apparent reduction in mitochondrial matrix were observed in old mice In addition the mitochondrial cristae were found reduced to small stumps These alterations of mitochondrial fine structure were not characteristic of the total complement of a cell s mitochondria for occasionally normal mitochondria and numerous intermediate stages could also be found Swollen and vacuolated mitochondria similar to those described by Weiss and Lansing (1953) were observed in the spinal ganglion cells of old rats by Hess (1955) However in pigment free spinal ganglion cells of young and adult guinea pigs Hess (1935) reports comparable mitochondria

The fine structure of mitochondria is known to vary with metabolic condition (Dempsey 1956) and to be highly susceptible to even slight variations in preparative technique The conclusion of Hess (1955) therefore might be appropriately quoted Since degenerative mitochondria can be found in young and adult cells and normal mitochondria are seen in senile cells it is difficult at least for individual spinal ganglion cells to use the condition of the mitochondria as an index of ageing

NEUROFIBRILS

Fine fibrils have been described in many types of cells In nerve cells these are designated as neurofibrils and are readily demonstrated by silver impregnation The relation of such fibrils however to the in vivo state of the neuron is not yet known Fibrils have been observed in the living neurons of cultured chick spinal ganglia (Weiss and Wang 1936) but that these are comparable to the conventional neurofibrils has been questioned (Hughes 1954) Electron micrographs which also fail to demonstrate conventional neurofibrils perhaps offer an explanation of how these structures are formed in silver impregnated specimens and why they are not found in living cells Palay and Palade (1955) describe submicroscopic intracellular filaments of indefinite length and 60 A–100 A in diameter and suggest that their side-to-side aggregation in addition to the deposition of silver may account for the appearance of neurofibrils in conventional preparations (Palay 1956*a* 1956*b*) It thus may not be unreasonable to consider the neurofibrils as an artifactual expression of the submicroscopic organization and age associated changes of the neurofibrils perhaps may be considered as indicative of age associated changes of the neuronal ultra structure

The aging of neurofibrils has been discussed above in reference to the neurofibrillar change of Alzheimer In addition aging of neurofibrils has been described in cerebral and cerebellar cortex medulla oblongata spinal cord spinal ganglion and sympathetic ganglia of humans by (Sosa 1952) According to Sosa a lipochrome neurofibrillar degeneration may be observed in aged subjects which is characterized by three stages (1) dissociation and

agglutinization of the normal neurofibrils due to the accumulation of lipochrome pigment which causes adhesion of the neurofibrils (2) the formation of a dense ring of agglutinated neurofibrils around the pigmentary network as the process continues and (3) the fragmentation of the network into irregular pieces and finally neurofibrillolysis

CHROMIDIAL SUBSTANCE

Chromidial substance characteristically found in the cytoplasma of a variety of cells occurs in most nerve cells in the form of discrete bodies These Nissl bodies are commonly demonstrated in sections of nervous tissue by means of staining with any of several basic aniline dyes usually toluidine blue or thionin and are believed to be involved in protein synthesis The Nissl substance may perhaps represent a readily available metabolic reserve to be utilized during cellular activity for changes in the normal size shape staining intensity and distribution of the Nissl bodies appear to be associated with varying physiological and pathological conditions

In general a survey of the gerontological literature tends to indicate a decrement in the normal amount of Nissl material concomitant with advancing age This is perhaps to be anticipated for a common conception of cellular aging is a decline in the cells normal metabolic activity A developmental sequence such as proposed by Andrew (1938) by which Nissl substance is believed to appear and degenerate in human Purkinje cells may serve as an example of this general concept

9 weeks–5 months	No discrete Nissl bodies diffuse basophilic material at the base and sides of cells
7 months 2 years	Nissl substance finely *granular with no definite* arrangement except that in the base of those cells in which the Nissl granules are most abundant aggregates are formed
5 years–50 years	Nissl bodies abundant and large concentrically arranged about nucleus and at periphery of cells
Over 50 years	Nissl substance decreased in quantity

There will according to Andrew (1956*a* 1956*b*) always be some cells in which the Nissl bodies retain their youthful size shape and distribution but their capacity to stain with basic dyes (i e their basophilia) decreases with aging

Any attempt to evaluate these data must take into account that all specimens were from autopsied material that a relatively small number of subjects comprised each age group and that there was considerable variability in results However there are similar reports of scanty or more faintly stained Nissl material in cerebral cortical cells of old rats (Kuhlenbeck 1954) Purkinje cells of mice (Andrew 1937) and human Purkinje cells (Ellis 1920) In brains of old dogs density and basophilia of Nissl substance are reported to vary with age and al o with the specific part of the brain (Palionis 1952)

That the opposite may be true (i e that an increase in Nissl substance is associated with aging) is suggested by Vogt and Vogt (1946) And there is good indication that when great care is taken to avoid post mortem autolysis and fixation artifacts no changes in the structure of the Nissl substance nucleolus or nucleus can be detected Thus in healthy old guinea pigs fixed immediately after death by formalin perfusion Wilcox (1959) was unable to differentiate between young and old tissues on the basis of basic staining Similarly Bondareff (1957*b*) has shown no noticeable differences in old and young rat spinal ganglia stained with toluidine blue and fixed immediately after death by freezing and drying (Fig 13) Such data suggest that both chromatolysis and hyperchromatosis are preparative artifacts and not related to cellular aging There may however be another explanation of these data

The studies of Dolley (1917, also see



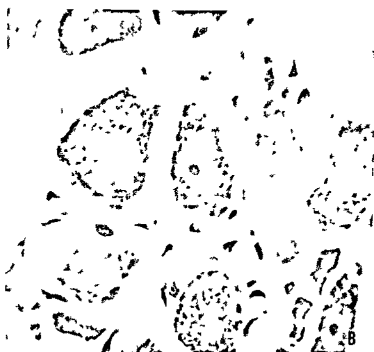


FIG. 13.—Spinal ganglion neurons from Sprague Dawley rats fixed by freezing and drying and stained with toluidine blue. *A*, from female rat, age 2 months; *B*, from female rat, age 24 months.

Kuntz 1945) may provide a basis for treating these apparently separate events (normal chromophil substance chromatolysis and hyperchromatosis) as different sequential manifestations of the same phenomenon According to Dolley (1917) the initial response to functional stimulation is an increase in nucleolar activity resulting in the increased production of Nissl substance Were aging considered in these terms hyperchromatosis might represent an initial stage The second stage recognized by Dolley is characterized by a decline in the hyperchromatic condition and a reduction in the chromidial content of the cell As the process continued chromatolysis would become more severe and an exhausted cell free of Nissl bodies would result

There appears to be an inverse relation between the quantity of Nissl substance and the accumulation of lipofuscin pigment An example of this may be found in the course of lipofuscin deposition in the profundum intermedius nucleus of the human amygdaloid complex as described by Sanides (1957) In subjects 40 years of age fine lipofuscin granules were found in all cells and the Nissl bodies appeared normal as to structure and quantity By 58 years a decline in the amount of Nissl substance was observed and correlated with an increase in the amount of lipofuscin As the lipofuscin steadily increased the Nissl substance was observed to gradually decline

In the dentate nucleus of old human subjects Hopker (1951) has reported that of those few neurons containing no demonstrable lipofuscin 4 per cent possessed Nissl bodies and that 1 per cent did not In those with intracellular lipofuscin pigment 72 per cent were found to contain Nissl bodies while in 23 per cent no Nissl bodies could be observed Since the histological appearance of the Nissl substance is frequently affected by various agents and is usually a fairly reliable indicator of neuronal well being Hopker in agreement with Burger (1947) concluded that lipofuscin is not necessarily injurious to the cell but is merely a non toxic decomposition product remaining in cells which possess no enzymatic system for metabolizing it

Unfortunately not many studies have dealt with these phenomena and in general questionable methodology subjects those that have to considerable criticism The reaction of the Nissl substance to various unfavorable environments can hardly be questioned but that aging is reflected in the morphology of the Nissl substance remains uncertain The microspectrographic investigations of Hyden (1955) have however contributed considerably to the understanding of these phenomena

The basophilic staining of the Nissl substance has been shown to depend upon the presence of pentose nucleic acid (for literature see Hyden 1955 and Gersh and Bodian 1943) which appears to be present as liponucleoprotein (Hyden 1955) This may be quantitatively estimated by such methods as selective cytochemical staining microcytochemical analysis of single cells X ray microradiography and ultraviolet microspectrography Most frequently employed of these are the various methods of selective staining which are ideally suited to qualitative analyses A quantitative analysis such as is usually required if one attempts to compare basophilia of young and old cells is generally not readily derived from stained sections and Hydén (1955) has warned against the use of histological stains to estimate the amount of pentose nucleic acid in the cytoplasm Hence the estimation of Nissl substance pentose nucleic acid based on the comparison of histological Nissl preparations may as already indicated be misleading

According to Hyden (1952) the chemical constitution of a nerve cell undergoes continuous change throughout life so that by the age of 50 years it is completely different from that of a child In the cytoplasm the liponucleateid (Nissl) substance declines with increasing age and is replaced by a lipoproteid of another composition which contains a complex chro-

matophore (lipofuscin) Thus in a ventral horn cell preparation from a human subject 50 years of age an ultraviolet absorption spectrum shows two absorption maxima (2670 A and 3700 A) characteristic of pig ment in add tion to the 2600 A maximum of Nissl material (Fig 11) Hyden has shown that if such a preparation is di gested with ribonuclease and then photo graphed in ultraviolet l ght at 2570 A the Nissl substance present before digestion d sappears and typical pigment granules are observed

NUCLEUS AND NUCLEOLUS

Morphological alterations of the nucleus and its component parts have been often associated with neuronal ag ng Changes in size shape distribution and staining prop erties of the nucleus and nucleolar appa ratus have been described as age depend ent Of these the following which have been reviewed by Andrew (1956*a* 1956*b*) are perhaps most commonly quoted (1) decreased contrast between nucleus and cytoplasm in stained preparations (2) in creased basophilia of the nucleoplasm (3) occurrence of atypically shaped nuclei and (4) alteration of normal intracellular posi t on of nucleus and nucleolus Similarly descriptive changes in nuclear structure have been discussed by Matzdorff (1948) namely diffuse nuclear staining clumping of the previously finely divided nuclear chromatin and shrinkage of nucleus and cytoplasm

More specifically in aged human sp nal gangl on neurons Hodge (1894) reported a failure of the nucleoli to stain with osmium tetroxide occurrence of shrunken irregularly shaped nuclei and a loss of the capacity of stained nuclei to darken as a result of fatigue In the cerebral cortex of old rats Kuhlenbeck (1944 1954) found shrunken and elongated nuclei loss of nu clear cytoplasm c contrast in stained speci mens and in some cells nuclear pycnosis and homogenous Nissl material combined with hyperchromatosis Contrarily Bailey (1953) found pycnosis and chromatolysis not significant in old human ventral horn cells

Reference has already been made to Bondareff (1957) and Wilcox (1959) in relation to Nissl material In carefully fixed *specimens of young and old rat and guinea* pig these two investigators observed no noticeable alteration of nuclear and nucleo lar structure

The numerous studies of Caspersson (1950) and Hydén (1955) concerned with the functional relation between the nucleus and cytoplasm indicates that the nucleolus is intimately involved in protein synthesis It appears that during embryonic develop ment of a neuron the nucleolus is formed from a specific portion of the nuclear chromatin which is displaced by the ex panding nucleolus to the outside periphery of the nucleolus and is termed nucleolar associated chromatin (Caspersson 1950) Pentose nucleic acid and basic proteins are reported to occur in the nucleolus and the nucleolar associated chromatin reputedly contains desoxypentose protein (Hyden 1955) During protein synthesis it is be lieved that nucleolar proteins diffuse to ward the nuclear membrane on the outside of which intense product on of pentose nucleic acid occurs (Caspersson 1950) and that the amount of cytoplasmic proteins increases at the same time Hyden has shown that in general these events occur during neuronal recovery following axon section (see Caspersson 1950)

From the laboratory of C and O Vogt has come evidence that events similar to those described by Caspersson and Hydén may accompany neuronal aging As an ex ample of this Klatzo s (1954) study of the nucleolar apparatus in the medial and lateral nuclear masses of the human palli dum will be described

In fetuses of 8 months Klatzo (1954) found well formed nucleoli with prominent nucleolar associated chromatin (*Randkor perschen*) The nucleoplasm was relatively clear and Nissl substance sparse especially in the pallidum lateralis Neurons of adults

appeared as usual the nucleolar associated chromatin was not so prominent and seemed to be composed of fine granules a clear vacuole variously placed was observed in the nucleolus Circumscribed areas of increased density associated with the nuclear membrane suggested that in a manner similar to that described by Caspersson (1950) the nucleolar apparatus is concerned with the synthesis of Nissl material

The involution which occurs with advanced age was characterized by the accumulation of lipofuscin pigment which in agreement with Hassler (1938) was observed first in the lateral nucleus There appeared to be an increase in the nucleolar associated chromatin (*Randkorperschen*) nuclear hyperchromatosis and enlargement Then as the involuntary process continued the nucleolar associated chromatin reverted to fetal like condition and the nucleolus which throughout the life span had remained of constant size shrank Nuclear shrinkage was also observed This process was accompanied by a gradual increment in lipofuscin pigment and an associated decrement in Nissl material (chromatolysis)

Other reports from the same laboratory have tended toward the development of a similar concept of cellular aging Such studies have focused upon age changes of the nucleolar apparatus in the nucleus coeruleus (Beheim Schwarzback 1955 1957) the presubiculum (Olszewski 1947) Ammon s horn (Beheim Schwarzback 1955) the hypothalamus (Buttlar Brentano 1954) and the thalamus (Schiffer 1957) The report of Buttlar Brentano (1954) presents additional observations whereby the occurrence of multiple nuclei and nucleoli are associated with advanced age Andrew (1956*b*) in his review of aging in the nervous system has dealt with these data and following Vogt and Vogt (1946) interprets them as indicative of defense or reactive phenomena which he has listed as follows (1) increase in size of cells (2) development of multinucleate cells (3) division of nucleoli and (4) increase in nuclear basophilia

The functional implication of these studies considerably influenced by the writings of Caspersson (1950) are perhaps obvious During periods of normal activity a well formed basophilic nucleolus and prominent nucleolar associated chromatin characterize the neuron and presumably support normal neuronal function Then as aging progresses and the normal metabolic machinery begins to fail the synthesizing capacities of the nucleus appear to decline Perhaps as certain of these data indicate a compensatory reaction manifested by increased nuclear and cytoplasmic basophilia occurs at some time during the gradual functional decline which at least suggestively accompanies aging Two other equally speculative interpretations however are possible

In the first place it is possible that those morphological phenomena which appear to indicate hyperactivity—that is nuclear and cytoplasmic hyperchromatosis enlarged nuclei and nucleoli and abundant nucleolar associated chromatin—may be totally unrelated to the aging process They have been observed mainly in human material and may be indicative of the acute alteration of the *milieu interieu* immediately preceding death for death due solely to the weight of years if it occurs at all is probably an exceedingly rare phenomenon Thus what may appear to be a compensatory hyperactivity due to aging may reflect a final compensatory burst of activity due to severe damage from which the neuron never recovers Such apparently occurs after axonal section though in this case the cell recovers (Hydén 1955)

Second the effect of preparative artifact should by no means be underestimated Supposed age changes in neuronal structure especially those of a purely qualitative nature such as change in shape or spatial displacement of the nucleus or nucleolus are extraordinarily difficult to evaluate When as is the case in most studies of human material it is usually not

possible to study sufficiently large numbers of subjects the possible effect of preparative artifact may be paramount In addition to artifacts of post mortem autolysis and fixation which have already been discussed mention should be made of technical artifacts for example sectioning When a microtome knife is passed through a paraffin imbedded tissue mechanical displacement of cellular components can result and at least in some cases could account for apparent structural duplications or displacements Although an age associated or pathological change in a tissue might be responsible for such an artifact appearing with greater frequency in an old rather than a young specimen interpretation of these data should not exclude a thoughtful consideration of such possible sources of artifact

With non human tissues it also appears necessary to evaluate critically morphological data in terms of the methodology employed for as Cox (1936) has shown even rough handling of a tissue prior to its fixation can cause the appearance of shrunken pycnotic cells which in many ways mimic those reportedly due to aging

CYTOPLASMIC GROUND SUBSTANCE

It is perhaps obvious considering the data which have been presented above that in the senium there are probably cytoplasmic changes of a more fundamental nature either chemical or structural In defining these the primary impediment seems to rest in the cytological fixation procedures which are usually of such a gross nature as to conceal the relatively subtle age changes

A meager histochemical literature indicates that there are probably enzymatic changes in the cytoplasma of neurons during the senium In dog autonomic ganglia for example Sulkin and Kuntz (1952) have shown that there is no age associated change in intracellular alkaline phosphatase However in glial cells from old dogs there was less of this dephosphorylating enzyme than in young animals Contrarily it has been stated by Bourne (1957*a* 1957*b*) that there is greater dephosphorylating enzyme activity in old cells Cortisone phosphate ethanolamine phosphate and carbamyl phosphate which are according to Bourne (1957*a* 1957*b*) mainly dephosphorylated in nuclei were found to possess greater activities in old than young cells Cytoplasmic dephosphorylation of pyridoxyl phosphate similarly was reported to be of greater activity in old cells In the nervous system these observations apply to the cerebellum and nuclei of the medulla oblongata of rats 3 months and 3 years of age These data appear to be in essential agreement with those of Weinbach and Garbus (1956 1959 see also above p 160) and Bourne has speculated that as a result of this dephosphorylating capacity of old cells a decrease in the concentrations of metabolically important substances might occur and result in inadequate functioning and eventually death

In autonomic ganglia of dogs less than 30 days of age Sulkin and Kuntz (1952) have reported that there is less ascorbic acid than that found in older age groups and that a marked decline occurs after 12 years It has also been found (Sulkin 1955) employing the periodic acid Schiff reaction that there may be more mucoprotein in the ganglion cells of dogs over 10 years

Alterations of fine structure of cytoplasmic ground substance appear still more elusive than their chemical counterparts elucidation depending directly upon the appropriateness of the method of fixation Currently employed methods of fixation are such that it has thus far not been possible to evaluate age changes directly in cytoplasmic ultrastructure although indirect determinations have been made In this regard perhaps one of the oldest concepts which because of technical limitations has never been adequately tested is that with aging there is a disruption of the normal colloid system of the protoplasm Associated with a decrease of water it has

been claimed that there is a relative increase in the solid component (gel phase) leading to the eventual deposition of intracellular material such as lipofuscin and *extracellular formations* such as senile plaques (Braunmuhl, 1932, Sjovall 1932) There has never been a valid demonstration of these phenomena and the conclusion, of course is sheer speculation Recently, however preliminary electron microscope studies of rat nervous tissue fixed by freezing *and drying indicate that a colloidal change* such as has been proposed may occur (Bondareff, 1957)

Indirect evidence tending to indicate a change in the submicroscopic morphology of spinal ganglia cells from old rats have been described In preliminary studies it was *noticed* that tissues *from old animals* react differently than do those from young animals when treated with silver nitrate and it is believed that the duration of the post mortem period prior to fixation is critical in such studies (Bondareff 1957*b*) Similar data have been provided by Hermann (1952) who treated human heart ganglia with a modified Bielschowsky silver impregnation method

THE SYNAPSE

It has been shown that conduction velocity in rat myelinated nerve does not de*crease with advanced* age and hence can not be related to the increased reaction time characteristically demonstrated (Birren and Wall 1956) That an increased spinal synaptic delay may be responsible is indicated by the electrophysiological study of Wayner and Emmers (1958) Morphological investigation of the synapse has not been rewarding In a study of selective synapses in the spinal cord and lower brain stem of one 17 year old dog Rasmussen (1959) found 'no remarkable abnormalities or loss of bouton terminaux

IV Conclusion

That the vertebrate nervous system *changes with age is indicated* by a vast morphological literature Relevant observations, however, must be approached with considerable caution, for, although an age change is implied merely by an observation being more *frequently made in the aged*, the inherent error of individual observations is often considerable Thus it is seldom possible to isolate aging from the host of other variables such as pathologies during life lesions arising while moribund and autolysis after death

A major problem of gerontology is the interpretation of the already described morphological phenomena in terms of a biological process of aging, although currently employed methods of cytology are apparently insufficiently sensitive to permit such interpretation readily However, as there appears to be a structural *substratum* of normal neural function and since age *changes in behavior appear to be mediated* by the nervous system, there must be structural correlates of aging It is probable that such correlates are of submicroscopic proportion, and primarily because of aug*mentation by* cytological procedure they are made manifest at a microscopic level

The morphological intricacy presented by this problem may seem formidable, but meaningful resolution does not appear impossible A majority of cytological data suggests that a general area of investigation most promising to the elucidation of cellular aging will be submicroscopic morphology of the neuron and its extracellular environment The methods of submicroscopic and perhaps even molecular morphology offer a means of access, but even they are not yet sufficiently sensitive to be compatible with such an elusive phenomenon as 'aging ' We may hope to further our understanding of cellular aging as these methods of cytology are critically applied to gerontological problems

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VI

Neurophysiology of Aging

JOHN W MAGLADERY

I General Considerations

As evaluated by predominantly motor responses to given situations living creatures perform most effectively in early adult life In man, as judged by the challenges of athletic or military competition this crest is reached surprisingly early in the life span When responses are less demanding of maximal motor speed or power or experience based on memory attains greater importance, optimal performance may be achieved somewhat later In any case however the prime is succeeded by progressive functional decline throughout the remaining years This process though in many instances operative throughout the major portion of the whole life span may be termed that of aging Certain features of it are documented in considerable detail in the chapters of this handbook dealing with sociological psychological and psychomotor studies

It would seem probable that the phenomenon of decline however slow or subtle is accompanied by certain biological processes operative at cellular or integrative levels and susceptible to relatively precise anatomical biochemical or physiological analysis That such is not the case at present has already been indicated and will be re emphasized in subsequent chapters In fact biological criteria of the process of aging are few scattered and in many instances equivocal

This is of course not surprising since the functional significance of those basic mechanisms which have been examined for indications of aging is in most instances poorly understood This is perhaps especially true in relation to the nervous system its sources of information from its environment and self and its guidance of motor activity through ultimate contraction of muscle As examples considerable data exist on stretch reflexes receptor organs or functionally different regions of cerebral cortex yet their roles in total voluntary or involuntary motor responses to the challenges of life remain at this time obscure Since it is in constituent basic mechanisms such as these that we search for physiological indications of aging these interpretive gaps loom large

Moreover in experimental studies as well as in purely social or professional appraisement observers are continually faced with the problem of whether in fact they are evaluating solely the results of growing old Even with selected laboratory populations usually of necessity restricted to small animals elimination of unrelated disease such as arteriosclerosis renal insufficiency or malnutrition as complicating factors in the older individuals is difficult or impossible In human assessment the problem is greater Hospital or ambulant patient populations are composed entirely of people (whether of 40 or 80 years) who have either disturbed sensory experience or some disorder of expression In many instances these disabilities are clearly due to recognizable pathological processes and not

to the mere passage of time Among active older members of the community less mani fest disease processes whether primarily of nervous system or of other tissues may well exist and their functional results be taken incorrectly as indications of normal aging For example ischemic damage to nerve pathways from slight degrees of peripheral vascular disease whether arteri osclerotic or associated with mild metabolic disturbances may well exist though not clearly evident even to competent exam iners Likewise minor degrees of pulmonary or cardiac disease through slight reduction in oxygen availability or blood flow to cen tral nervous system may interfere with complicated psychomotor reactions Early stages of Parkinsonism with concomitant slowing may readily pass unnoticed In deed any critical observer as well as one focusing attention on particular experimen tal situations must constantly question whether functional disabilities however minute may conceivably be explained on a basis of normal aging Do they often or always represent the results of additional pathological processes of cumulative or peculiarly senile nature? Is in fact life span always so limited by actual disease that pure aging effects on the nervous sys tem never become apparent? It is true that certain minor clinical abnormalities are sufficiently common in older age groups that they are generally accepted as indica tion of normal aging (Critchley 1956) yet their absence in many older persons tends to invalidate this suggestion to some de gree In short it must be recognized in clinical assessment of older people as well as in more basic physiological studies of them that objective criteria apart from changes in total performance are far from unequivocal and even these may not nec essarily be due alone to aging It is only therefore with full recognition of these limitations that any current review of a few necessarily isolated physiological stud ies may reasonably be undertaken

II End Organs

RECEPTOR

It is conceivable that part of the de creased rate of response encountered with the passage of years is due to impaired excitation of end organs activated by vari ous stimuli from the environment This might be associated with actual impaired excitability in the sense organs themselves but might equally well be due to factors interfering with their effectiveness For ex ample there seems little doubt that ad vancing years bring decreased light perme ability of lens (Friedenwald 1930) cornea (Burger and Schlomka 1928) and vitreous (Friedenwald 1952) Although precise studies of these cumulative effects are lack ing it is apparent that they may play some part in the steady fall in visual acuity as age progresses (Friedenwald 1952) Less convincing evidence of interfering factors has been demonstrated in relation to other end organs Babbitt (1947) however pre sented some indication that atrophic changes in supporting walls of external auditory canals in aged persons diminishes the size of the external orifice and thus lowers acuity of hearing Thresholds of cutaneous sensibility might well be raised by the altered collagen and elastic tissues of aging skin (Dick 1947 Ma and Cow dry 1950) It is pertinent therefore to take into serious consideration these pos sible interfering factors when assessing re sponses to visual auditory and tactile stimuli which have for the most part been investigated in human subjects

Nevertheless there is evidence to suggest that increasing years do bring some im paired excitability of certain end organs themselves The subject is discussed in con siderable detail in chapter xv Sensory Functions of this handbook It is there fore sufficient here merely to direct atten tion to the phenomenon and leave until later any assessment of its functional im portance in the total aging process

EFFECTOR

Although some degree of muscular wasting and weakness is commonly found in advanced old age, and more particularly in peripheral parts of the body (Critchley, 1956), the reviewer knows of no convincing demonstration, whether anatomical or physiological, of alterations due solely to aging on peripheral effector mechanisms—myoneural junctions and skeletal muscle It would be surprising if, in fact, such did not occur to some degree At the same time, however, it may be apt to draw attention once more to the possibility that impeding factors, such as joint cartilaginous and ligamentous changes, may make difficult the assessment, in humans, of various forms of motor activity in the aged

III Peripheral Pathways

AFFERENT

It is well recognized by clinicans that in the elderly, careful testing commonly reveals some impairment in sensibility to applied stimuli, whether visual, auditory or somatic Increased threshold for perception rather than qualitative differences in recognition, is the usual finding Decreased appreciation of light touch is regularly encountered Equally evident are diminution in recognition of slight degrees of joint movement (Laidlaw and Hamilton 1937) and vibrations caused by tuning forks (Pearson, 1928, Birren, 1947 Cosh 1953) Tendon jerks and other simple reflex phenomena dependent on intact afferent pathways may be decreased or absent In all these instances, as well as in elevated thresholds for vision and hearing impeding factors at end organs, as mentioned previously, may be operative to some degree It is more difficult however, since free nerve endings are involved, to incriminate such factors in the raised threshold to pain which Critchley (1956) stresses as a common normal geriatric finding It must be stated however, that not all clinicians would agree with this observation concerning pain Clearly, it is in need of careful verification

These clinical observations suggesting some change, with increasing years, affecting afferent pathways might be due to alterations in peripheral nerves or dorsal roots or equally well within central nervous system itself at spinal or higher levels Regardless of possible central changes, there is considerable histological evidence to indicate that some, at least of the aging process occurs peripherally The papers of Cottrell (1940) and Semenowa Tjan Schanskaja (1941) for example show that

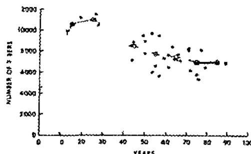


Fig 1 —Field graph of myelinated fibers in eighth thoracic dorsal root up to 85 years ● = individual cases O = decade averages (Courtesy of K B Corbin and E D Gardner and the Editor of the *Anatomical Record*)

in aged peripheral nerves there is convincing diminution in the number of larger fibers and a consequent shift of the spectrum toward the smaller side Even more painstaking and revealing have been the analyses of dorsal spinal roots performed by Corbin and Gardner (1937) (see Table 1 and Fig 1) and by Rexed (1944) Particularly in lumbosacral regions, there is in aged persons evident fiber decrease, again in numbers of the largest fibers. That similar changes, unrelated to frank arteriosclerotic or other pathological processes, occur in optic nerve is much more debatable (Fuchs 1920) Although reduction in numbers of cochlear nerve fibers has been described in elderly persons (Rasmussen, 1940), that this represents solely an effect

TABLE 2*

ISCHEMIC AND POST ISCHEMIC PARESTHESIAE IN 93 NORMAL SUBJECTS WITH 10 MINUTE OCCLUSION TESTS (SERIES I)

	Age Group			
	A (12 30 Years)	B (31 45 Years)	C (46 60 Years)	D (61 84 Years)
No of subjects	24	25	25	19
a) Ischemic Paresthesiae				
Incidence of I P				
Definite	24 (100%)	18 (72%)	18 (72%)	7 (37%)
Doubtful	0 (0%)	1 (4%)	4 (16%)	1 (5%)
Absent	0 (0%)	6 (24%)	3 (12%)	11 (58%)
Mean intensity (+grading)				
All subjects	1 9	1 4	1 1	0 5
'Definites'	1 9	1 8	1 6	1 1
Onset (min) after occlusion in those with definite I.P				
Mean and (S D)	1 4 (0 42)	1 5 (0 58)	2 1 (1 00)	1 8 (0 56)
Limits	0 8–2 5	0 5 2 8	0 8–3 5	1 0–2 5
Duration (min) of definite I P (to limit of occlusion)				
Mean and (S D)	6 1 (1 66)	6 4 (2 05)	5 5 (1 55)	6 0 (2 90)
Limits	2 5–9 2	3 0–9 5	3 5–8 7	2 5–9 0
No with I P to or above mid fore arm	4	4	2	0
b) Post-ischemic Paresthesiae				
Incidence of P I P				
Definite	24 (100%)	25 (100%)	25 (100%)	15 (79%)
Absent	0 (0%)	0 (0%)	0 (0%)	4 (21%)
Nature No with undoubted sharp pricking	24 (100%)	25 (100%)	21 (84%)	7 (37%)
Mean intensity (+grading)	2 4	2 2	2 1	1 1 (all cases) 1 4 (with P I P)
Per cent lacking accentuation by "tapping"	4% (24 assessed)	29% (17 assessed)	53% (19 assessed)	62% (13 assessed)
Onset (min) after circulatory release in subjects with P I P				
Mean and (S D)	1 0 (0 24)	1 0 (0 26)	1 1 (0 35)	1 4 (0 34)
Limits	0 6–1 5	0 6–1 5	0 7–2 5	0 9–2 7
Duration (min)				
Mean and (S D)	5 3 (1 80)	4 6 (1 14)	4 2 (1 37)	2 6 (1 64) (all cases) 3 3 (1 11) (with P I P)
Limits	3 5–11 7	2 3–6 5	2 2 7 1	0–5 5
No with P I P confined to fingers	2 (8%)	3 (12%)	4 (18%)	6 (32%)
Post ischemic muscle twitching				
Present	73%	75%	67%	50%
Severe	36%	8%	7%	7%
	(22 assessed)	(12 assessed)	(15 assessed)	(14 assessed)

* Courtesy of E W Poole and the Editor of the *Journal of Neurology Neurosurgery and Psychiatry*

fibers with aging must be considered un settled Certainly, if present and distinct from the everlasting problem of unrelated disease, they are meager

IV SEGMENTAL LEVELS

Degrees of organization at spinal-cord and brain stem levels of the central nervous system are adequate to permit highly com plex patterns of posture and reflex response (Sherrington, 1906, Walshe, 1914, Kuhn, 1950) Furthermore, under certain patho logical conditions, integrated motor dis charges can produce in spinal animals high ly organized rhythmic movements (Luttrell and Bang 1957) It would seem reason able, therefore, to search in mechanisms at these segmental levels for indications of aging within the central nervous system itself This would seem especially pertinent, since certain relatively simple stretch re sponses, such as tendon jerks often de pressed in the aged, may become more active through reinforcement (Jendrassik 1894) from higher levels (Hoffmann, 1922 Paillard, 1955, Johns *et al*, 1957)

Histological grounds for suspecting much alteration from simple aging at these spinal cord and brain stem levels remain how ever, slight A little demyelination in pos terior part of fasciculus gracilis and "pig ment atrophy" of certain ganglion cells appear to be the only consistent changes, and even these are subject to question as to etiology (Bailey, 1953) Simple physio logical studies have been few and insuf ficient

Knowlton and Britt (1949) in an early abstract, described latency measurements of patellar reflexes in persons ranging in age up to 42 years. Unfortunately, older age groups were apparently not studied From investigations on ankle jerks (Teas dall *et al* 1952) to which monosynaptic reflex discharge normally contributes at least a part (Magladery *et al* 1951), it would be surprising to detect in man sig nificant and measurable latency changes in elderly people Certainly, differences of 2–3 milliseconds from person to person could well be lost in the prolonged muscle action potential or could be attributed to shift to polysynaptic response which may occur with spinal cord damage (Teasdall and Magladery, 1956) Recently, however, con vincing evidence of increasing synaptic de lay with age has been provided by Wayner and Emmers (1958) Monosynaptic reflex discharge was measured in rats ranging in age from 113 to 859 days (see Table 4) Central delays were progressively greater throughout the series Moreover, the in

TABLF 3*

MAXIMUM CONDUCTION VELOCITIES OF ULNAR NERVE FIBERS TO MUSCLES OF THE HYPOTH ENAR EMINENCE AT VARIOUS AGES

Age in Years	No of Subjects	Average Conduct on Velocity (M/Sec)	Standard Dev ation
3 5–10	8	61 5	6 30
10–20	8	57 1	6 19
20–30	35	58 4	4 28
30–40	7	57 4	6 45
40–50	2	56 8	
50–60	3	49 7	
60–70	10	51 3	5 26
70–82	10	51 5	7 26

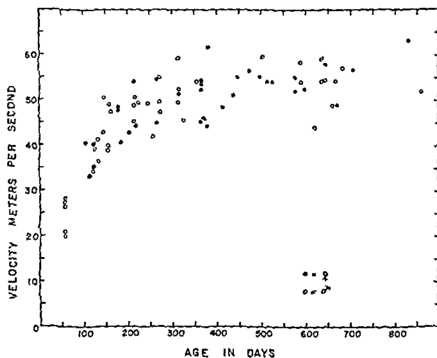
* Courtesy of I H Wagman and H Lesse and the Editor of the *Journal of Neurophysiology*

crease with age was regular and unbroken, indicating decreased excitability at single synapses and not conversion to a poly synaptic response That this almost two fold increase in central delay is related to aging changes inherent in the motoneurons themselves is of course, not proved or im plied by the authors It might well be as sociated with alterations to other neuronal pathways converging on the motoneuron pool (Eccles and McIntyre, 1953)

Certain more complicated reflex mecha nisms, such as normal plantar flexion re sponses and superficial abdominal reflexes for example, are generally considered spinal in nature, though highly dependent on potentiation from higher centers (Gowers, 1892, Brain, 1951, Pedersen, 1954) Cer-



logica)



VELOCITY METERS PER SECOND
0
10
20
30
40
50
60
100
200
300
400
500
600
700
800
AGE IN DAYS
● = ♀
○ = ♂

tainly, they can be normally present with high spinal cord lesions, although more commonly they are replaced by Babinski responses (Kugelberg, 1948) and absence of abdominal reflexes In a large series of normal persons and patients Pedersen (1954) found no significant differences in latency of either type of flexion response between young persons or people of 60 years No older subjects were apparently studied, and action potentials were not recorded from small foot muscles, seemingly a most important locus of this reflexly

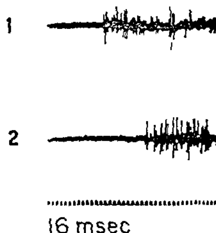
TABLE 4*

MEAN SYNAPTIC DELAYS AND THE *t* VALUES OBTAINED FOR THE DIFFERENCES AMONG SIX GROUPS OF RATS

Group	Age Range (Days)	No of Subjects	Mean Synaptic Delay	*t*	*p*
I	113 22	5	0 97		
				5 588	<0 001
II	269-76	4	1 14		
				2 768	< 05
III	461-90	4	1 23		
				3 607	< 01
IV	776-859	5	1 36		
				2 747	< 05
V	868-82	3	1 86		
				8 416	<0 01
VI	274 83	2	1 13		

* Courtesy of M J Wayner and R Emmers and the Editor of the *American Journal of Physiology*

produced muscular response of flexion More recently, however, it has been clearly shown (Magladery *et al*, 1958) that central delays of these complex flexion responses, as well as those of superficial abdominal reflexes, do in fact increase in aged people (see Fig 4) Moreover, the common increases are of considerable magnitude (of the order of 100 milliseconds) In neither of these reflexes is there good reason to suspect intrinsic anatomical alterations in the propriospinal pathways (Magladery *et al*, 1958) The results emphasize, rather, potential prolongation of relatively low-level responses when potentiation from higher centers may be diminished In the case of monosynaptic reflex discharge, and the processes subserved by such, this increased delay cannot be of great functional significance in terms of any one motoneuron pool When cumulative, however, and particularly when processes such as these are operative over complex spinal reflex arcs which are more dependent for excitation than single synapses on influences from higher centers, these increased central delays may be very important indeed They may well be sufficient to account for good proportions of the slowed motor response times in the elderly



Similar studies of aging effects on relatively simple segmental responses which are also influenced from higher centers have been few The investigations of Kumnick (1954, 1956) do, however, draw attention to their possibility Kumnick convincingly confirmed the common clinical observation that minimal and maximal pupillary diameters are progressively decreased with age Furthermore, the extent and rate of reflex response to light and other stimuli are less in the elderly Although she (1956) found evident increased latency of dilatation on recovery from light exposure in older individuals, she was unable to detect any

difference in latency of constriction These observations may be valid although their discrepancy would surprise clinicians On the other hand they may represent inadequacies of instrumentation The slow process of dilatation (of 2 or more seconds duration from Kumnick s figures) might well be detectable by her recording methods (100 millisecond intervals) It is quite possible however that latency of onset of the more rapid constriction could be in error by many mill seconds in any one individual—time values of potentially great importance

V Suprasegmental Levels

At these levels valid data are completely in the hands of other experimental disciplines Clinical phenomena accompanying advancing years are familiar to all (Critchley 1956) Subtle anatomical changes found in the elderly are dealt with elsewhere in this handbook Progressive slowing with age in total responses within wide ranges of activity and adjustment is repeatedly emphasized in many chapters and much of this may result from alterations to higher centers or integrative mechanisms

Unfortunately neither in experimental animals nor in man have physiological studies cast any light on the problem In this area of highest activity the inadequacies of functional interpretation are regardless of age most glaringly apparent Even apart from this difficulty the reviewer knows of no investigation of aging effects in an mals within any of the fields of interest to competent physiological investigators of cerebral basal ganglion or cerebellar function

In man possible physiological approaches have necessarily been limited and in terms of precis on crude It might be thought for example that studies of gross cerebral metabolic changes and cerebral blood flow in chapter vii Neurochemistry of Aging might reveal significant d ffer ences in the aged when compared with young people There seems little question but that in many elderly persons there is significant reduction in cerebral blood flow and oxygen consumption (Scheinberg *et al* 1953 Frazekas *et al* 1955, Kety 1956 Sokoloff 1957) and many others In these studies however differences were greatest in those elderly patients with obvious evidence of cerebral vascular disease or other organic brain damage Moreover comparison was usually made with young adults of normal activity In recent years considerable effort has been expended to make valid comparisons with these methods in people of various ages engaging actively in community life In brief such studies have shown that apart from the results of actual disease processes no significant alteration in cerebral blood flow or oxygen consumption can be detected in the normal elderly by present methods (Sokoloff 1958)

Another possible objective method of delineating to some degree indexes of cerebral activity with aging has been electroencephalography Numerous reports have been devoted to this subject (Mundy Castle 1953 Obrist 1954 Silverman *et al* 1955 Busse *et al*, 1956 Obrist 1957) Again differences among age groups have been meager equivocal and not clearly dissociated from unrelated disease For example Obrist and Bissell (1955) have emphasized the profound effects of slight degrees of cardiac insufficiency or cerebral vascular disease among groups of subjects in the incidence of electroencephalographic abnormalities Nevertheless there is some suggestion though statistically only that slight slowing of alpha rhythm and occasional increase in delta activity may be more common in normal elderly persons (Obrist 1954 1957) The functional significance of such findings is of course unknown and certainly they must be viewed with some question This is particularly so since Mundy Castle (1953) could find no difference among adult age groups in the electroencephalographic response to photic stimulation Focal changes in a relatively high proportion of active aged persons in the community (Busse *et al*, 1956), can

not reasonably be accepted as indication of normal aging since they suggest strongly the presence of local vascular softening

In short neurophysiological investigations limited as they have been have really added nothing to our knowledge of normal aging processes at high levels within the central nervous system Certainly they have in no way indicated structural or functional alterations which might serve as a framework for interpretation of more evident psychological changes That however is in no way to imply that aging processes do not (indeed they surely must) exist at metabolic or chemical levels or even in terms of physiological differences too subtle to detect by present methods

VI Conclusion

In this review limitations in neurophysiological knowledge of processes underlying normal aging have been repeatedly mentioned At several levels of complexity in the nervous system there have been slight or more evident indications in man of alterations which might have varying degrees of possible relevance to slowing in the aged Leaving apart the special sense organs degenerative changes at periphery in end organs and nerve pathways if valid cannot possibly account for more than a small fraction of the prolongation in motor response times encountered in the old and certainly they are inoperative in the late middle years of life At suprasegmental levels no physiological evidence of deterioration with aging has been forthcoming from our present methods of study Indeed here perhaps more than elsewhere vagaries of unrelated disease processes make study of human material unsuitable or confusing The prospects however for delineation of alterations of aging at these high levels in man are not completely dim when it is remembered that sizable differences in speed of spinal reflex responses may accompany mere subtle determination of handedness (Teasdall and Magladery 1958) Nevertheless it does not seem likely (at least with present methods) that objective functional evidence of aging changes in the nervous system itself either at periphery or at highest central levels will soon come from physiological studies in man It must be re emphasized however that no serious investigations of alterations due to aging have yet to the reviewer s knowledge been carried out on central physiological mechanisms in experimental animals of reasonable size and degree of organization It might well be that such could be fruitful

In humans however certain reflex responses of varying degrees of complexity and influence from higher centers are mediated through spinal cord and brain stem All the necessary elements for power posture and movement and its adjustment exist at segmental levels and certain at least of these mechanisms are susceptible to challenge in aging man For example though latency changes in simple tendon jerks are little if any altered by aging it may well be that higher regulation of their threshold under varying psychological situations (Paillard 1955) is quite different in the aging person Studies such as those of Paillard (1955) in older age groups might thus be productive At a somewhat more complex level and in a relatively inexact fashion it has already been shown (Magladery *et al* 1958 Teasdall and Magladery 1959) that latencies of normal plantar responses and abdominal reflexes are usually greater in the aged and by values which might have considerable functional relevance Moreover there is some reason to suspect that similar changes may well be encountered in pupillary responses There must be many and more functionally su table segmental mechanisms operative at these spinal cord and brain stem levels which are susceptible to study under well controlled conditions in man—convergence responses vestibular and postural reactions vasomotor reflexes and so on At all events this level of physiological functioning in man seems worthy of intensive investigation

The greatest shortage however or so it

seems to this reviewer, is in adequate neurophysiological studies in aging animals of a size suitable for such experiments Of considerable importance has been the lead given by Wayner and Emmers (1958)—a direct attack on segmental mechanisms in rats of different age groups Studies such as theirs might well be pursued on a much larger scale and directed toward a multiplicity of low level reflex responses of varying degrees of complexity Moreover despite the obvious demands on patience and cost there might well be considerable advantage in developing aging colonies of larger animals such as cats or primates about which a good deal of neurophysiological information already exists on segmental and higher mechanisms This would be especially necessary were adequate comparative studies of cerebral basal ganglion or cerebellar function undertaken Perhaps it is only by such means that it may be possible to investigate in a reasonable fashion those physiological processes which when altered by age lead to decreasing rate and precision of motor response

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VII

Neurochemistry of Aging

WILLIAMINA A AND HAROLD E HIMWICH

I CEREBRAL METABOLIC RATE IN VIVO

The study of the changes of the metabolic rate of the whole body with age is well established After a maximum value during the first decade of life on a basis of calories per square meter of body surface, the basal metabolic rate falls rapidly during the second decade and decreases more gradually in the following years The interpretation or the underlying processes is not clear, but Shock (1955) has suggested that the reduction in oxygen utilization depends upon a loss of cells from the body rather than a diminishing cellular metabolic rate Observations for cerebral metabolic rate have not received as definitive an evaluation, chiefly because of technical difficulties in acquiring this information The determination of the intensity factor, the ability to consume oxygen per 100 gm of brain per minute, has a somewhat wider methodological error than that for the oxygen utilization of the entire body The capacity factor, the total oxygen consumption of the brain, cannot be accurately determined without the in vivo weight of the brain, for which at present there are no quantitative methods Despite such handicaps we are nevertheless approaching valid solutions, at least for the intensity factor

Oxygen Cr Uptake/100 Gm Brain/Minute

The oxygen consumption of the brain, whether measured by the method of Kety and Schmidt (1945), the modification of Scheinberg and Stead (1949), or that of Lassen and Munck (1955) depends upon two factors namely, the oxygen utilized from the blood that passes through the [illegible]

obtained by subtracting the oxygen content of the internal jugular venous blood from the arterial value For the measurement of cerebral blood flow, the subject inhales either N_2O for 10 minutes or krypton 85 for 15 minutes Samples of blood collected during those periods are analyzed for nitrous oxide or krypton 85, and the integrated difference between the arterial and venous blood values is used to calculate cerebral blood flow (CBF) Table 1 presents normal values for young men (Kety and Schmidt 1948) We shall return to a discussion of the capacity factor in the consideration of total oxygen consumption of the brain of the aged

On comparing the brain metabolism of individuals below 40 years of age with older persons, the spread of the various figures for $CMRO_2$ is greater in the latter

group There are some values within the range of young persons but many more below the lower limits of that range Thus, if all observations are included the average becomes progressively lower with age especially after 60 Yet if only averages are considered we would lose a most important aspect of this problem of measuring CMRO in the aged As a step in understanding the causes of the impairment in $CMRO_2$ in old age it is necessary to correlate the metabolic data with the disease processes as well as the clinical diagnosis of each subject

A recent result of Sokoloff and his group (1957) reveals that in individuals averaging 71 years of age and selected for as great a degree of freedom from medical disease as possible cerebral blood flow and cerebral metabolic rate are within the limits found by the same methods in subjects who are in their twenties Thus in aged individuals chosen because of absence of the changes wrought by disease the intensity factor remains unchanged with age We therefore should turn next to the examination of CMRO in patients with frequent though not invariable associates of old age for example tendencies toward arteriosclerosis and hypertension Also to be considered is irreversible damage and destruction of brain tissue Such changes might affect $CMRO_2$ adversely

Hypertension unaccompanied by cerebral arteriosclerosis, however does not cause a significant change in $CMRO_2$ (Kety Hafkenschiel Jeffers Leopold, and Shenkin 1948 Hafkenschiel *et al*, 1954) even when associated with an augmentation of cerebrovascular resistance and a reduction in CBF (see Table 1) With aged mental patients whether the exact diagnosis can be specified or that of senile dementia is made by default both CBF and $CMRO_2$ may be significantly decreased (Freyhan *et al* 1951) Though extracerebral arteriosclerosis does not necessarily correlate with its presence in the brain in instances where arteriosclerosis is a prominent feature as for example after vascular stroke or with other indications of arteriosclerosis such as retinal changes and extracerebral arteriosclerosis a diagnosis of cerebral arteriosclerosis is made If the evidence is in favor of syphilis then one or another diagnosis involving cerebral lues is indicated such as syphilitic meningoencephalitis general paresis taboparesis or gumma On the other hand in patients without any feature pointing directly to a

TABLE 1

METABOLISM PER 100 GM BRAIN/MINUTE*

	Healthy Young Men†	Patients with Hypertension Various Ages‡	Patients with Hypertension 61 70 Years§	Patients 56 79 Years‖	Patients with Senile Psychosis♯	Healthy Aged Men Averaging 71 Years**
CBF (ml)	54	57	50	44	41	59
$CMRO_2$ (ml)	3 3	3 5	3 2	2 9	2 8	3 4
CVR (mm Hg)	1 6	2 8		2 4	3 0	1 5
AVO_2 (vol per cent)	6 3	6 2		6 5	6 8	5 85
RQ	0 99	0 90			0 95	0 91
Mean femoral arterial BP (mm Hg)	86	153		97	121	91 4

* In order to compare the data obtained by the method of Kety and Schmidt 1945) with those of Scheinberg and Stead (1949 in the case of the latter CBF and $CMRO_2$ are decreased by 15 per cent while CVR is increased by the same percentage

† Kety and Schmidt (1948 ‡ Hofkenschiel *et al* (1954) § *Ibid*

‖ Scheinberg *et al* (1953) ♯ Freyhan *et al* (1951) ** Sokoloff personal communication (1957)

particular etiologic factor the term senile dementia" is employed Parenchymal atrophy however occurs irrespective of the clinical diagnosis These results whether based on morphological evidence or on the measurements of CBF and CMRO do not yield the data needed to decide whether the primary cause lies in a deficient blood supply or in parenchymal damage Other observations however suggest that CBF is adequate despite cerebral arteriosclerosis and that the lower CBF is not the chief factor in the reduction in CMRO In patients with cerebrovascular accidents and therefore with some degree of cerebral arteriosclerosis the additional constriction of CBF imposed by the inhalation of 85–100 per cent oxygen (Heyman *et al* 1953) does not cause a decrease in $CMRO_2$ AVO_2 enlarges to make up for the further impairment of CBF That the arterial supply to the brain is not rigid in arteriosclerosis and therefore does not induce a fixed limitation to the CBF is also shown by the effects of inhalation of 5–10 per cent carbon dioxide (Scheinberg *et al* 1953 Shenkin and Novack 1954) or the use of hypotensive drugs (Fazekas Bessman Cotsonas and Alman 1953 Kleh and Fazekas 1954) for in most instances CVR is reduced and CBF is therefore accelerated as a result of such measures $CMRO_2$ remains unchanged On weighing these data Fazekas *et al* (1955) suggest that the fall in CMRO is probably not a consequence of a decreased supply of essential substrates a conclusion with which Lassen agrees (1956) Direct evidence on this question is afforded by preliminary studies of Sokoloff and co workers (1957) on patients diagnosed as suffering from chronic brain syndrome in whom the degree of impairment of $CMRO_2$ is more profound than the moderate fall in CBF These findings suggest that $CMRO_2$ is not reduced because of the limits set by the circulation of the brain The recent researches in brain metabolism have therefore failed to support the conception of the vascular etiology of chronic progressive organic brain disease and have de emphasized the importance of atheromatosis of the cerebral arteries except in instances of apoplectiform insults Instead our attention is now focused on the possible pathogenic role of primary cellular degeneration

The clinical complex of senile dementia exhibits characteristic symptoms and morbid anatomy Prominent behavioral changes are decreased intellectual ability forgetfulness of recent events emotional blunting and incontinence Air encephalography discloses a reduction in brain size and especially so in the cerebral hemispheres with cortical atrophy and ventricular enlargement Neurons exhibit chromatolysis and disappear while astrocytes may proliferate Though these regressive processes usually occur in the aged they are also occasionally seen in younger individuals the presenile dementias

The question of the significance of $CMRO_2$ in terms of behavior is still an open one despite a good correlation between decreases in $CMRO_2$ and behavior in certain selected instances. For example when physiochemical changes come on rather suddenly inducing a fall of $CMRO_2$ to approximately 2 0 environmental contact is lost as with surgical anesthesia produced by barbiturates (Himwich *et al* 1947 Kety Woodford Harmel Freyhan Appel and Schmidt 1948) unconscious ness caused by excessive alcohol (Battey *et al* 1953) the comas associated with diabetes (Kety Polis Nadler and Schmidt 1948) uremia (Heyman *et al* 1951 Scheinberg 1954) and hepatic disease (Fazekas and Bessman 1953) or due to large dosage of insulin (Himwich *et al* 1941 Kety Woodford Harmel Freyhan Appel and Schmidt 1948) Gross or microscopic morphological changes in the brain are also accompanied by reductions in CMRO as in the comas following apoplexy cerebral anoxia brain trauma and craniotomy (Fazekas and Bessman 1953) With tumors of the brain there is also a significant decrease in $CMRO_2$ (Kety Shenkin and Schmidt 1948) But when

we come to chronic conditions enduring over a period of years, the question becomes more complex

In the first place, patients with signs of dementia reveal a fall of $CMRO_2$ of the same order as that observed in the acute reductions in $CMRO_2$ mentioned above These chronic patients, however, are not comatose but instead exhibit other impairments of mental acuity such as the various degrees of dementia characteristic of chronic brain syndrome Linden (1955) reports similar decreases in $CMRO_2$ in acute apo

TABLE 2

METABOLISM PER 100 GM BRAIN/MINUTE

	1*	2	3	4
CBF (*ml*)	54 4	44 8	42 6	32 8
$CMRO_2$ (ml)	3 88	3 26	2 50	2 47
CVR (mm Hg)	1 69	3 57	3 07	3 99
MBP	89	149	123	122
AVO_2 (vol per cent)	7 13	7 50	6 15	7 56

* Legend
1 Normal adults ranging in age from 18 to 45
2 Patients with cerebrovascular accidents but without mental changes
3 Pat ents w th ce ebrovascular accidents with definite mental changes but ne ther restless nor comatose
4 Pat ents w th cerebrovascular accidents with severe mental



plexy whether the patients exhibit severe dementia or frank coma (Table 2) But in a series of observations on patients with senile dementia, a correlation was found between the severity of the intellectual defect and the decrease in $CMRO_2$ (Lassen *et al*, 1957) The literature, however, yields discordant notes on relationships between $CMRO_2$ and mental acuity Heyman *et al* (1953) found that the mean values for $CMRO_2$ were practically the same for patients with acute cerebrovascular accidents whether the patients were alert, confused, or stuporous Another example of failure in correlation between behavior and reduction in $CMRO_2$ is afforded by Fazekas *et al* (1952) with results obtained on patients 50 years of age or older and with cerebrovascular disease These patients were segregated into three groups according to their mental status, which varied widely despite a mean $CMRO_2$ which was practically the same in all three groups Those with old or recent cerebrovascular accidents exhibited a mean $CMRO_2$ of 2 2 and nevertheless were considered to have normal mental acuity The mean $CMRO_2$ of 2 0 was observed in patients with vascular disease who exhibited an abnormal status ranging from slight confusion to complete disorientation and 2 1 in patients with disturbances of consciousness ranging from stupor to deep coma

Psychotic reactions like those of schizophrenia insofar as they are not associated with apparent organic brain changes are, in general, not characterized by diminution in $CMRO_2$ In the case of schizophrenia the values for $CMRO_2$ and CBF were found to be either normal (Kety, Woodford, Harmel, Freyhan, Appel, and Schmidt, 1948) or slightly reduced (Gordan *et al*, 1955). Similarly, it might be expected that manic-depressive reactions might leave $CMRO_2$ unchanged Thus the type of psychosis must be taken into consideration in evaluating the significance of $CMRO_2$

A review of the present status reveals that the data are contradictory in regard to the relationship of $CMRO_2$ to behavior Comas of recent origin are usually associated with reductions of $CMRO_2$ up to 30–50 per cent Lassen *et al* (1957) have observed good correlations of $CMRO_2$ with the clinical, neurophysiological, and psychological estimates Each member of the normal group had $CMRO_2$ values varying between 3 6 and 3 2 Those belonging to the second group, whose dementia was questionable, revealed $CMRO_2$ of 3 2–3 0 Severely demented patients were significantly lower and varied from 2 8 to 1 6 But, as pointed out above, other investigators have failed to find such correlations

(Fazekas et al, 1952, Fazekas, Kleh, and Witkin, 1953, Heyman et al, 1953)

Comparisons between $CMRO_2$ and mental acuity have usually been made on a statistical basis, and in particular instances $CMRO_2$ may shoot wide either above or below the mean The method of Lassen and Munck (1955) produces more concordant results in individual patients, an improvement based on changes of technique, for they took the average of simultaneous bilateral determinations of $CMRO_2$ for each patient Himwich and associates (1946, 1947) had shown that there may be differences when bilateral determinations for AVO CBF, and $CMRO_2$ are made simultaneously Lassen (1956) has pointed out that bilateral determinations frequently reveal one high value and one low one and suggests that their average yields a better picture of $CMRO_2$ for the whole brain Despite the fact that individual values are less extreme the average for a whole series of observations would still probably be the same, that is a series of monolateral studies might be expected to yield the same average as a series of bilateral ones We must, therefore, seek some other reason for the conflicting results Perhaps a better clinical evaluation of the patients and especially of their mental status might exert a clarifying influence As emhasized by Lassen (1959) CMRO is differently affected in two kinds of mental disorders "functional" disturbances and dementia But these two kinds are not necessarily mutually exclusive, for both may be present in the same individual when a "functional" psychosis exists in a patient with chronic brain syndrome If the clinical data were reanalyzed from this viewpoint, a better correlation of $CMRO_2$ might be found

The spotty disappearance of cells over a long period of time presents a different clinical picture from that of a sudden functional loss of activity of most of the neurons as in conditions mentioned on page 189 all associated with coma It must be remembered however, that mental acuity is a poorly localized function and may require large portions of the brain to degenerate before impairment becomes evident For example, the faculty of awareness receives broad, crude contributions from the subcortex (Alman and Fazekas, 1957), but a more discriminative component is of cortical origin (Bailey, 1957) In any case, the cortex of the brain might be expected to bear the chief impact of the pathological processes but the differences in duration and pattern of attack upon the cortex determine the behavioral outcome In addition a functional reparation may be active in these patients It is not impossible that, as brain substances are destroyed, the remaining cerebral parts are released from their customary neural constraints and assume adaptive processes to diminish the impairment of brain function Thus, in the light of Hughlings Jackson's conception (1884) slow degenerative changes permit the development of compensatory functions even though these may not be as adequate as those they replace

In contrast to coma and dementia, "functional" aberrations are not characteristically associated with a decrease of CMRO We may therefore, conclude that in addition to the observation that comas of comparatively acute onset are associated with a fall in CMRO, slow regressive changes of the brain as observed with chronic brain syndrome, if severe enough, will also yield a low CMRO When "functional behavioral disorders complicate the clinical picture of dementia, they do not affect $CMRO_2$ which depends rather on the presence of irreversible damage to the brain and especially to the cerebral cortex

Oxygen Consumption of Entire Brain

What can we say on the oxygen uptake of the entire brain? Because CMRO represents the average oxygen consumption of 100 gm of brain per minute, in order to calculate the total oxygen consumption it is necessary to know the weight of the entire brain, and this information can be best obtained at autopsy For that reason we

can only surmise total oxygen utilization of the brain on a basis of information based on average figures obtained from other individuals Data detailed in the section on the constituents of the brain show that after a maximum value at about 30 years of age there is a gradual decrease in weight in males which becomes more profound after 70 years of age (see Table 3) The brain of females is somewhat lighter but in general follows the same pattern But, again as in the consideration of $CMRO_2$ be estimated It can be said, however, that when the determinations of $CMRO_2$ indicate a fall due to parenchymal loss as in chronic brain syndrome, it is logical to conclude that brain weight must have also decreased When multiplying $CMRO_2$ by the weight of the brain, the value obtained will be more impaired than could be expected just from the determination of CMRO alone

Is a reduction due to a banking down of the fires of life affecting all cells more or

TABLE 3

HUMAN BRAIN WEIGHT IN RELATION TO AGING

Appel and Appel (1942)			Burger (1957)			Leontovich (1938)		
Age	No	Mean	Age	No	Mean	Age	Men	Women
			16–20	119	1384	1–30		1240
12 24	19	1287	21 30	356	1394	15–30	1377	
30–34	105	1376	31–40	342	1375	31–50	1354	1201
35–39	109	1333						
40–44	141	1339	41 50	293	1358			
45–49	151	1327						
50–54	182	1327						
			51–60	271	1345	50–92	1316	
55 59	164	1302				50–98		1183
60–64	199	1307						
			61 70	202	1310			
65 69	257	1310						
70–74	303	1283						
			71 80	88	1263			
75–79	223	1259						
80–84	126	1254						
			81–90	55	1161			
85–96	39	1232						

it must be emphasized that these are average figures made up of determinations on many individuals some may retain brain weights within the normal range of the young adult and others suffer significant decreases It is obvious that even with a normal $CMRO_2$, total brain oxygen uptake would be diminished if brain weight is decreased with age Only those individuals with both brain weight and $CMRO_2$ within the normal range for mature individuals would have an oxygen consumption of the total brain unchanged How many individuals belong to such a favored group cannot less equally, or is it a result of the loss of individual neurons? Information from histological studies of Brody (1955) and others indicates a loss of cells This process be

processes On the other hand, replacement with glial tissue would have the reverse effect and should reduce the deficit in CMRO Yet the algebraic sum accounts for a reduction in weight The evidence seems to indicate that a diminution in $CMRO_2$ is a quantal process occurring as

cell after cell is lost rather than by a slow regression of metabolism in all the cells of the body

II Foodstuff of the Brain

It is generally acknowledged that the brain uses carbohydrate almost exclusively for maintenance of structure and function (Himwich 1951) It has been reported above that the AVO difference of the human brain usually averages 6 3 volumes per cent (Himwich 1951) This indicates a glucose oxidation of approximately 8 4 mg per cent Actually the brain extracts more sugar from the blood usually about 10 mg per cent Thus the amount of glucose removed by the brain in each circulation is more than enough to explain the utilization of cerebral oxygen consumption On the other hand the normal resting brain releases 1 6 mg per cent of lactic acid and 0 22 mg per cent of pyruvic acid Thus when the amount of glucose which is not oxidized but instead is split into lactic and pyruvic acids is taken into consideration the total utilization of glucose can be explained within the experimental error of the methods used (Himwich and Himwich 1946) It is of interest that the respiratory quotient of the brain obtained from human beings as well as animals is approximately 1 0 also indicating the oxidation of carbohydrate (Himwich 1951) It is not improbable however that other substances are oxidized not only the metabolites of the Krebs cycle (Sacks 1956) but also different substrates (Sacks 1958) But it should be noted that all foodstuffs other than glucose are not consumed in sufficient quantities to support brain metabolism during hypoglycemia which is therefore associated with a marked fall in CMRO and the production of coma In the aged the quality of the nutrients used by the brain remains largely unchanged though the respiratory quotient is somewhat reduced Recent observations by Sokoloff *et al* (1957) reveal an AV glucose difference of 7 8 mg per cent Though this value is smaller than utilization of glucose in younger adults it is still slightly in excess of the amount that can be accounted for by oxidations on a basis of the AVO_2 difference of 5 85 volumes per cent for these aged individuals

III Chemical Analysis of Human Brain

Difficulties of Analyzing Human Brain Post Mortem

The problems of studying human brain *in situ* at any age are vexing but post mortem studies also present serious difficulties In the first place brain tissue is usually obtained from a person who has died and only seldom from the living individual Even tissues removed from the brain during an operation are rarely normal and may show the effects of adverse conditions such as pressure from an adjacent tumor But the changes which have taken place in the brain before the individual died are more far reaching As an example of this in attempting to perform metabolic studies of the various parts of adult human brain, we made Warburg determinations of oxygen consumption of cerebral areas from an individual who died in uremic coma We found that in this brain the only portion which approached the expected oxygen consumption was the medulla oblongata (Himwich unpublished data) In other words the various parts of this brain had been in a dying state for a considerable period of time before the individual succumbed In addition to the deleterious effects of the immediate cause of death upon brain tissue there are also changes associated with arteriosclerosis and other chronic diseases such as senile psychoses and hypertension These complicating factors all tend to apply more to the brain of the aged than to that of the younger individual

A second group of problems dealing with human brain includes the prompt signing of autopsy permits the rapid cooling of the body and the time required to remove and sample the brain Under the conditions of our hospital where every effort is made to facilitate these operations to the utmost a

minimum of 2 hours is required before the samples of brain can be frozen or otherwise prepared for analysis These circumstances, which form at the moment insurmountable obstacles are such as to render completely worthless the analysis of many substances which are known to be sensitive to rapid autolytic changes In this group we could put as outstanding examples energy rich compounds such as adenosine triphosphate, phosphocreatine and readily metabolized substances such as glucose and glycogen At the other end of the spectrum, however, are certain materials like total nitrogen, cholinesterase and phosphatases which probably do not change significantly for some period of time following the death of the individual It is necessary under our present conditions to confine analyses to materials such as these less unstable com pounds

IV Brain Weight as Related to Aging

One of the analytical problems which ap pears at first to be very simple is that of determining the true weight of the brain This however is also subject to a number of difficulties The research carried out by Essex and his colleagues (Edstrom and Es sex 1956) have shown that, in the guinea pig anoxia of no longer than 30 minutes duration will increase the water content of the brain approximately 4 per cent and therefore add to the total weight of that or gan Although the weight of guinea pig brain continues to rise for several hours after death, that increase which occurs in the first 30 minutes is at a much faster rate than subsequently It seems likely, however, that in dealing with human brain, where we have a large number of cases, this factor may be relatively constant, and re sults obtained at various ages may be com parable With this difficulty in mind, it is worthwhile to consider what we know of the effect of age upon the weight of the brain We have been able to find three extensive studies in the literature One is from the Russian (Leontovich 1938) The actual data are not available but we do have a summary of what he has found (Table 3) He shows a decrease in brain weight after the age of 40 in both men and women Ap pel and Appel (1942) have also reported the variations in brain weight with age in instances in which they considered the brain to be free of lesions The numbers of individuals in each age group of 5 years ranged from 61 to 257 In this study the authors found the highest mean brain weight in the ages 30–34, with a progres sive decline from that aged onward (Table 3) It is interesting however, to look at the ranges of brain weight in each of the age classes The greatest variation actually oc curs in the age range of 65–69 years, in which there were 257 cases In this group there were some specimens which were heavier than the heaviest for the ages of 30–34 and none as light as some of those in this group Again as we will emphasize throughout this chapter, individual varia tion in the changes of the brain accom panying aging are wide We can only guess at how important this factor is, since we have no means of even beginning a quanti tative estimation In other words at any age level there may be individuals whose brains by all our criteria appear to be younger than the chronological age would suggest just as there may well be mem bers of the same group with brains which weigh less and seem to be older The third study on the weight of human brain comes from the laboratory of Max Burger This German scientist (1957) has combined his own data and those from two other authors to obtain a total of 2187 brains from men and 1489 brains of women These patients, who in all cases were free of neurological or psychiatric disease, probably represent the autopsies at a general hospital The average brain weight for men in Burger's summary seems to reach a peak between 20 and 30 years of age and after that decline mark edly (Table 3) In the case of women, the brain weight never reaches the same level as does that of men, and the highest figure is also in the third decade of life These

three sets of data from widely different sources seem to indicate that brain weight increases to approximately the age of 30, declines slightly in the next two to three decades, and then falls more rapidly toward old age. These changes should be taken into account in judging any quantitative data given on the constituents of the brain. Such data are usually given in terms of milligrams per cent or some comparable figure. In interpreting cases in which there appears to be agreement in the percentage composition in old and young brain, it must be remembered that there probably are differences in the total amounts of constituents present because brain weight has declined.

It is very difficult to say what is happening to the histological picture of the brain as it ages. The group headed by Andrew (1956) believes that numerous changes occur in the central nervous system as the individual ages. Another group, whose opinion is voiced by Windle (1956), feels that most of these changes are secondary to other conditions in the body such as cardiovascular disease or to variations in the techniques used to fix and stain the brain. As has been pointed out above, one of two conditions prevails in the brain though not to the extent of being mutually exclusive: either the cells of the central nervous system become changed and hence do not metabolize as efficiently or with the same pattern that they did formerly or the cells remain normal but become reduced in number. If the latter assumption is valid, neuronal metabolism would not change with age, although there would be a change in the number of metabolizing units.

V. Establishment of the Period of Senescence

For purposes of comparison of brain composition at various age levels, it would be helpful to establish the age at which we might expect to find changes due to aging. Those who have been interested in the developing brain, such as Koch and Mann (1913) and McIlwain (1955, chap. xi), had divided the brain into four histological stages of development for comparison of the concomitant chemical maturation. These four periods are those of (1) cellular division, (2) cellular growth, (3) myelinization, and (4) completion of myelinization and growth. For those, however, who are dealing with the problems of aging in the central nervous system it would be advantageous to add a fifth stage, that is, senescence. While it is true, as noted above, that we do not have agreement upon what happens histologically in this period, it may be that if we examine the chemical data available we will be able to demarcate it in terms of chemical constituents. It is difficult to determine at what age this period of senescence starts. There are a number of criteria, lacking definitive histological ones, to consider. We may use the age at which a downward trend of the curve of brain weight begins. If we review the data presented by Burger (1957) alone this would mean that we would choose 30 years for both men and women. Comparison of the data of Appel and Appel (1942) suggests that the same age ranges might be taken for the beginning of senescence, as do also those of Leontovich. However, if we study the graph prepared by Burger (Fig. 1), we can pick, instead of the point at which there is the first decline in brain weight, a later point at which this decline becomes precipitous. In that case, 70 years would be the beginning of old age. In the same way, if we look at the data of Appel and Appel (1942) we find that there is a big drop between the average for ages 70–74 as compared with that for the age group 65–70. Therefore for the purposes of this chapter, it is convenient to consider the age of 70 as the beginning of the fifth period of brain change, that is, the period of senescence.

Before we settle on the age of 70 as the final one we should look at other possible criteria as to what is happening to the brain, for example, the relation between the water content of the brain and the total solids. Although the concentration of water

is known to increase after death, we are for the purposes of this analysis assuming that this artifactual increase is at a relatively constant percentage at all ages From the data of Burger (1957) who has studied the percentage of moisture in 378 brains from male and female subjects, we find that for both sexes the lowest water content occurs in the age group between 21 and 30 (Fig 2) After this time there is a tendency for the moisture to be more or less at the same level until the age group 61–70 If both men and women are considered together there is a definite increase after the age of 70 in the water content Thus the rise in this constituent affords another reason for choosing 70 as the beginning of the senescent period The total solids in the brain reflect, of course, merely the reciprocal of the water and, hence, give us approximately the same age as the end of the maturation period or the beginning of the fifth stage

It is worthwhile to consider the age of senescence in brain in relation to the total lipid content Since the majority of the lipids are present in the myelin sheaths, the

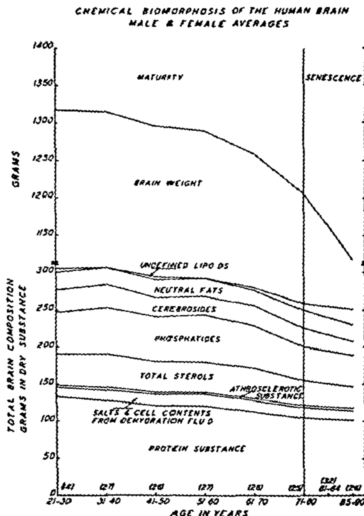


FIG 1 —Changes in brain constituents and brain weight. Brain constituents are calculated on a basis of dry weight whereas the weights of the entire brain include all constituents as well as water (Adapted from Burger, 1957)

attainment of a constant figure for total lipids might be expected to indicate maturity and a decline to mark the period of senescence It is interesting to study the report of Burger, who has data from 319 men and 298 women on this point The percentage of total lipid for all subjects increases to 70 years and declines after that time although the fall is very slight between 71 and 80 years and becomes more acute thereafter If we look at the graph for chemical biomorphosis of brain (Fig

VI Influence of Age on Constituents of Whole Brain

Using these four bases namely, brain weight water content, total solids and total lipids for demarcating the beginning of the senescent period it seems reasonable to say that it commences at 70 years of age Therefore for this analysis of the effect of aging we will compare data on brains obtained from individuals 70 years or older with those from younger persons The level

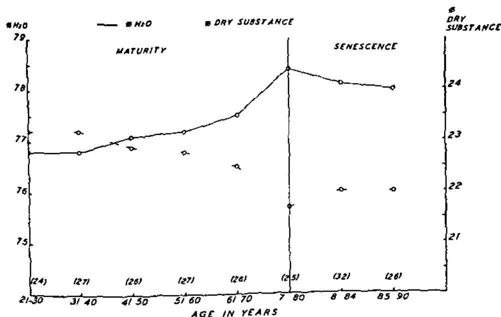


Fig 2 —Water and total solids in human brain with aging Numbers in parentheses are brains analyzed for each age group (Adapted from Bürger 1957)

1) we find that after the age of 61–70 there is a marked decline in all the lipid fractions with the exception of the unidentified fraction Tilney and Rosett (1931) report on four brains from individuals between 32 and 59 years of age inclusive with an average water and lipid content for whole brain of 78 7 and 11 1 per cent respectively Their values for a 76 year old person (81 2 and 9 3 per cent for moisture and total lipid respectively) reflect the same general trend shown above

of constituents in the 40 year span between attainment of maximum brain weight (30 years) and the beginning of the senescent period will be considered the mature level

For a complete study on the constituents of the human central nervous system the best reference is that of Burger (1957) Not only has he analyzed for more substances than has any other single investigator but he has included a greater number of specimens within the various age groups As stated above his data suggest that after

70 years of age there tends to be an increase in water and a decrease in total solids of the brain (Fig 2) This change is progressive and is accompanied by a fall in *protein content in most lipid fractions* and in the total inorganic materials of the brain (Fig 1) However when we consider the inorganic substances separately the picture is varied Nitrogen sulfur and phosphorus all show a fall in percentage of dry matter up to 70 years of age This decline is merely a continuation of the reduction of these with the rise in the unidentified lipid fraction Burger suggests that in the brain of the aged individual there is the formation of a sulfur lipid compound which he calls a *clinker ' substance that is it does not contribute* significantly to cellular function Probably, it accumulates because it is metabolized more slowly than it is formed It would be interesting to see what relation this has to the yellow plaques or to the lipochromes which have been described by several histologists in human brain (Hyden

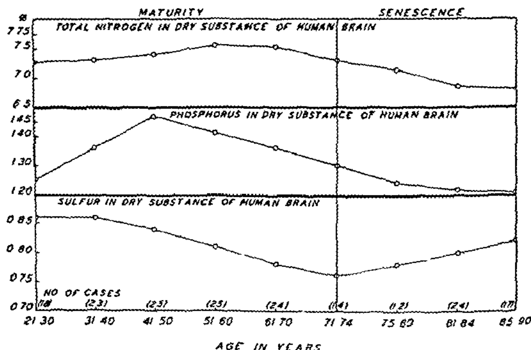


Fig 3 —Changes in total nitrogen phosphorus and sulfur in human brain with aging (Adapted from Burger 1957)

substances which have been evident for some years (Fig 3) In the case of nitrogen and phosphorus the values are progressively lower If the nitrogen data are recalculated to a fresh tissue basis the fall still is evident (Table 4) This translation of the data is important for comparison with the results of animal brains discussed later in the chapter For sulfur in contrast there is a marked augmentation after the beginning of the age of senescence especially in women Taking this increase in sulfur together 1955) and by Sulkin in aged dogs (1955) If there is as Burger s data suggest a marked increase in this material in the brain accompanied by a fall in the vital fractions such as nitrogen and phosphorus and an augmentation of water, there must be in the period of senescence a progressive loss in the amount of functional brain tissue Burger (1957) points out that in old age there occurs also a physiological hydrocephalus As the cerebral tissues shrink the ventricles enlarge and these

cavities as well as the available space between skull and brain are filled by cerebrospinal fluid.

Burger (1957) has determined the amount of desoxyribonucleic acid (DNA) present in the dry matter of the brain as well as in the 'lipid free protein framework.' His method depends upon the determination of the ribose constituent of nucleic acids. In both fractions of brain he found parallel changes with age. The low point for DNA is in the third decade, the time at which the brain reaches its greatest weight (Fig. 4). From then on, DNA increases so that in the group of patients 90–93 years of age it is higher than at any other time in the life-span. Because dry matter of the brain decreases steadily from the third decade of life through the ninth, it is important to estimate if this apparent increase is a real one in terms of the total amount of DNA present in the brain. To answer this question, we have calculated the grams of dry matter on the basis of the average size brain for each decade of life (Table 5). On this basis we find that the total amount of DNA is increasing in the brain in much the same fashion as was shown by the graph of percentage of DNA in dry tissue. These data suggest that in the aging brain, although there is loss of protein and of lipid, there may be at the same time an increase in DNA, which may

TABLE 4

AGE AND TOTAL NITROGEN OF HUMAN BRAIN

Age (Years)	Dry Substance (Per Cent)	Nitrogen (Per Cent)	Nitrogen in Fresh Tissue* (Per Cent)
21–30	23.2	7.27	1.69
31–40	23.2	7.30	1.69
41–50	22.9	7.40	1.69
51–60	22.8	7.55	1.72
61–70	22.5	7.53	1.69
71–74	21.7	7.28	1.58
75–80	21.7	7.12	1.55
81–84	22.0	6.85	1.51
85–90	22.0	6.80	1.50

* Calculated from Bürger's (1957) data on percentages of dry substance and of total nitrogen in dry substance.

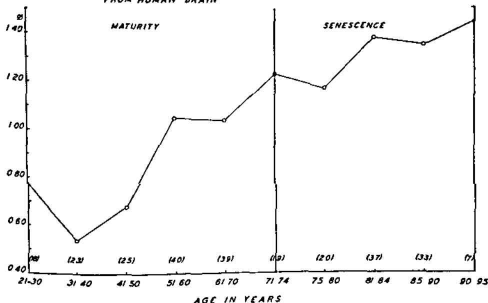


FIG. 4.—Desoxyribonucleic acid contents of human brain in relation to aging. Numbers in parentheses are brains analyzed in each age group. (Adapted from Bürger, 1957.)

be imputed in part to a proliferation of the glial elements These cells are doubtless less rich in both protein and lipids than are the neurons per se perhaps because the glial cells largely represent structure Burger (1957) suggests that the increase in old age is due to two factors an increase in pykno sis of the neurons and growth of glial ele ments These recent data from Burger s laboratory add to those of Hyden (1955) who found a decrease in PNA (pentose nu cleic acid) in the cytoplasm of brain cells from aged animals

TABLE 5

AGE AND DESOXYRIBONUCLEIC ACID IN HUMAN BRAIN

AGE (YEARS)	BRAIN WEIGHT* GM)	DRY WEIGHT*		DNA* (PER CENT)	DNA GM)
		Pe Cent	G ams		
16–20	1384	22 2	307 2	0 75	23 04
21 30	1394	23 2	323 4	0 77	24 90
31–40	1375	23 2	319 0	0 54	17 23
41 50	1358	22 9	311 0	0 68	21 15
51–60	1345	22 8	306 7	1 05	32 20
61 70	1310	22 5	294 8	1 23	30 65
71–80	1263	21 7	274 1	1 23	33 71
81–84	1166†	22 0†	256 5	1 17	30 01
85–90	1166†	22 0†	256 5	1 38	35 40
90–93	1166†	22 0†	256 5	1 44	36 94

* Adapted from Bu ger 95
† Average g ven by Bu g 1957 fo 81 93 y ars

VII INFLUENCE OF AGE UPON BIOCHEMICAL MAPPING OF THE BRAIN

Data are even more sparse on the effect of aging upon distribution of chemical sub stances in various areas of brain than on composition of whole brain Although the Kochs (1907 1909 1916) made some bio-chemical determinations of various parts of the human brain the cases are so scattered in regard to age as to make any definite statements about the effects of aging im possible MacArthur and Doisy (1918–19) divided the specimens they studied into forebrain, cerebellum and brain stem and made complete analyses of all three parts However their results are usable only for discussion on immature and mature brains since their oldest person was 67 years old Randall (1938) studied several areas of human brain but makes no statement as to the age of his subjects

Tilney and Rosett (1931) compared the water lip d and non lipid material in cere bral hemispheres cerebellum and brain stem If we average their figures for the years 32 through 59 (four brains), and compare them with those for the brain of a 76 year-old individual the cerebellum and the hemisphere show an increase in water content a decline in total lipid and a smaller fall in the non lipid fraction at 76 years The brain stem on the contrary has no change in water and an augmentation in total lipid Unfortunately these authors re-port only one brain from a person over 70 years old This difference in aging of the brain stem as compared to the cortex and cerebellum if confirmed would make an in teresting basis for speculation (Table 6)

Brante (1949) in his extensive work on the lipids of the brain stud ed mostly young brains and only the cortex or gray and marrow or white on older ones Both these parts showed a rise of water after 70 years of age At the same time the total solids decreased as did also all the lipid fractions with the exception of the cerebro-sides of the cortex (Table 7) but not of white matter where these compounds are more abundant

An interesting study by Schaus (1957) has been made on the ascorbic acid content of human pituitary cerebral cortex heart and skeletal muscle in autopsy material The highest level of ascorbic acid in the mature brain is in age group 30–39 years (Table 8) In the eighth decade of life all parts with the exception of heart muscle show a marked decerase The fall occurs even when the ascorbic acid is calculated on the basis of tissue nitrogen which ex cludes apparent variations due to changes in moisture content It is impossible to tell how much these decreases reflect dietary in adequacy

Variations in Samples from Different Anatomical Areas

"The corresponding segments of corresponding areas" (Tilney and Rosett, 1931) of cortex differ considerably in their chemical constituents in the right and left hemispheres Gorodissky (1925) was the first author to comment on chemical assymetry of human brain She analyzed samples from the frontal pole the cuneus, and the ante

TABLE 6*

PERCENTAGE WATER AND LIPID CONTENT OF HUMAN BRAIN PARTS

Age	No	Cerebral Hemispheres			Cerebellum			Brain Stem		
		H_2O	Total Lipid	Total Non lipid	H_2O	Total Lipid	Total Non lipid	H_2O	Total Lipid	Total Non lipid
32 59	4	78 5	11 1	10 4	81 2	8 1	10 7	74 8	11 3	13 9
76	1	81 4	9 1	9 5	82 9	7 2	9 9	75 0	14 8	10 2

* Adapted from Tilney and Rosett (1931)

TABLE 7

PERCENTAGE WATER AND LIPID CONTENT OF GRAY AND WHITE MATTER OF HUMAN BRAIN

	Age	
	55 65	72 90
	Cortex	
No	2	6
Per cent water	83 6	86 5
Per cent total solids	16 4	13 5
Total lipids (per cent fresh tissue)	5 4	5 1
Phospholipids (per cent fresh tissue)	3 2	2 8
Cholesterol (per cent fresh tissue)	0 8	0 7
Cerebrosides (per cent fresh tissue)	0 7	0 7
	Marrow	
No	4	4
Per cent water	70 7	73 3
Per cent total solids	29 3	26 7
Total lipids (per cent fresh tissue)	18 7	15 9
Phospholipids (per cent fresh tissue)	8 0	6 7
Cholesterol (per cent fresh tissue)	4 2	3 6
Cerebrosides (per cent fresh tissue)	5 2	4 2

* Adapted from Brante (1949)

rior and posterior sections of the central gyrus for various lipid fractions The differences between samples taken from the same areas in the right and left hemispheres were marked (Table 9) Tilney and Rosett (1931) in analyzing ten cases for percentage of water and total lipids found four brains in which there were differences between the right and left hemispheres or the right and left cerebellum as far as total lipid content was concerned They concluded that the method for determining lipids was technically difficult enough to account for the discrepancies which occurred In agreement with Gorodissky, the opposite conclusion was reached by W A Himwich *et al* when they analyzed different parts of human brain using the same procedure that they had concomitantly employed to study the left and right halves of rabbit brain Four rabbits showed a total nitrogen content of the right half of the brain of 1 70, 1 71, 1 70, and 1 70 per cent, respectively, and 1 74, 1 71, 1 71, and 1 75 per cent, respectively, on the left side In four human brains picked at random (Table 10) discrepancies greater than 1 per cent of water content and 0 1 per cent nitrogen content can be found in eight out of twenty three pairs of samples for water and

in eight of these samples for nitrogen On a dry weight basis these differences would be even larger These data emphasize the necessity of defining exactly the anatomical area from which samples are taken in reporting quantitative information on brain constituents Similar bilateral differences in nitrogen and cholinesterase content of right and left paired samples of cat brain also occur (Himwich unpublished data) We are inclined to believe that these differences are real and that they are not seen to the same extent in the lower animals such as the rabbit and the rat because of the greater uniformity and the relative non-specificity of function of the cortex (Lashley, 1944) In the case of the assymetry of human brain we must also consider the effects of a longer life span and of disease It is interesting in this regard to note that Streicher (1957) also reports definite differences in calcium content of the right and left sides of whole rat brains

Comparison of Biopsy Specimens with Tissue from Autopsy

One of the problems attending any type of analysis of the brain as has been dis

TABLE 8*

ASCORBIC ACID CONCENTRATION IN HUMAN PITUITARY CEREBRAL CORTEX MYOCARDIUM AND PECTORAL MUSCLE

Age Group	Pituitary		Cerebral Cortex				Myocardium				Pectoral Muscle			
	No †	Mg/Gm Wet Weight	No †	Mg/Gm Wet Weight	No †	Mg/Gm Tissue Nitrogen	No †	Mg/Gm Wet Weight	No †	Mg/Gm Tissue Nitrogen	No †	Mg/Gm Wet Weight	No †	Mg/Gm Tissue Nitrogen
30-39	6	0 988	6	0 180	6	14 1	5	0 055	5	1 8	4	0 043	4	1 6
40-49	4	447	5	122	5	10 4	5	038	5	1 5	5	028	5	1 1
50-59	15	521	16	140	14	11 1	13	030	12	1 3	14	030	13	1 2
60-69	17	511	16	153	16	11 4	14	040	14	1 6	13	033	13	1 0
70-79	4	497	11	149	11	11 9	11	039	10	1 6	10	031	10	1 2
80-89	1	0 455	1	0 103	1	8 0	4	0 049	2	2 1	3	0 019	1	0 4

* Adapted from Schaus (1957)
† No of specimens

TABLE 9*

ANALYSES OF AREAS OF HUMAN BRAIN

Area	Total Nitrogen	Cholesterol	Phosphorus of Unsaturated Phosphatids	Alcohol extracted Lipids
Frontal pole				
Right	1 20-1 40	0 54-0 59	0 0600-0 0700	2 40-2 50
Left	1 40-1 60	51 59	0650- 0725	2 40-2 60
Cuneus				
Right	1 50-1 60	76- 80	0626- 0750	2 90-3 10
Left	1 30-1 60	66- 75	0625- 0725	2 70-3 10
Anterior central gyrus				
Right	1 70-1 90	86- 90	0725 0750	3 20-3 50
Left	1 56-1 65	90- 95	0725- 0800	3 00-3 20
Posterior central gyrus				
Right	1 50-1 70	69 74	0700- 0750	2 80-3 00
Left	1 60-1 70	0 71-0 89	0 0700-0 0725	3 90-3 10

* Adapted from Gorodissky (1935)

cussed above (p 193), is the possibil ity that changes occur in the brain during the period before autopsy We have been fortunate in obtaining two types of mate rial from the operating table (1) cortex from temporal lobectomy for the relief of psychomotor epilepsy and (2) superficially normal[1] frontal tissue removed during the course of extirpation of a brain tumor In each case the material was frozen rapidly in dry ice and acetone and maintained *frozen* until the analyses were made For comparison with these we picked the tem poral pole samples from three patients who were autopsied 2 5 4, and 5 hours, respec tively after death These samples were taken in the cold room, wrapped in foil and waxed freezer paper, and stored at —22° C until analyzed

Comparison of the data (Table 11) shows that autopsy material is higher in glutamic acid than is tissue taken from liv ing brain and frozen This increase is un doubtedly the result of autolytic changes in brain following death which lead to a breakdown of protein Even the earliest sample taken at 2 5 hours shows the effect of time to increase both glutamic acid and glutamine These data illustrate the diffi culty of chemical determinations on autop sy material Probably analyses of such brain tissue is worthwhile and yield quan titative data only for the most stable brain constituents It is imperative that we study exhaustively the process of aging in the brains of animals for exact values But it is questionable how far data from animals can be used to interpret changes in human brain This point is discussed elsewhere in this chapter (p 206)

TABLE 10

PERCENTAGE WATER AND NITROGEN CONTENT OF PAIRED PARTS OF HUMAN BRAIN

AREA	CASE NO							
	17		18		19		20	
	Total N trogen	H_2O	Total N trogen	H_2O	Total N trogen	H_2O	Total N t ogen	H O
Frontal pole								
Right	1 73	82 3	1 72	81 7	1 34	82 0	1 74	81 9
Left	1 64	83 6*	1 61*	82 0	1 74	81 7	1 72	82 6
Frontal cortex								
Right	1 62	83 1	1 72	80 0	1 64	79 8	1 74	81 6
Left	1 53	82 9	1 73	80 8	1 76*	81 1*	1 74	81 8
Temporal pole								
Right	1 57	83 6	1 70	83 1	1 70	82 9	1 78	83 6
Left	1 69*	82 9	1 62	82 2	1 63	81 5*	1 63*	83 4
Occip tal pole								
Right	1 85	80 8	1 78	80 6	1 74	79 3	1 78	79 8
Left	1 77	82 6*	1 84	80 5	1 79	78 3*	1 84	80 2
Caudate nucleus								
Right			1 59	82 2	1 89	80 0	1 76	82 7
Left			1 84*	82 8	1 88	80 9	1 76	82 1
Thalamus								
Right	1 88	80 7	1 66	81 8	1 83	79 3	1 77	79 9
Left	1 72*	81 8*	1 94*	79 4*	1 68*	79 4	1 88*	77 2*

* Differen e between r ght and left more than 1 0 per cent for water or 0 1 per cent for n trogen

[1] Histological examination of a portion of the sample showed some pressure necrosis

VIII Cerebral Metabolic Rate of Animals Obtained by in Vitro Methods on Minces Homogenates and Mitochondria

Early evidence obtained with minced tissue reveals maximal metabolic rates for brain parts both in rats (Tyler and van Harreveld 1942 Chesler and Himwich 1944) and in dogs (Himwich and Fazekas 1941) at the age of about 6 weeks and a fall thereafter in values observed on adult members of these two species This evidence does not indicate a decrease which is the same in all areas of the brain On the contrary there is a difference in the rate of decline in oxygen utilization among various parts These studies on minced brain do not yield evidence on aging animals for they do not disclose whether or not the values observed in the mature animals are maintained throughout life or suffer a further decrease It is however suggestive that at least in one dog 10 years of age the values for the oxygen consumption of various brain parts are lower than in younger adults (Himwich unpublished data) (see Fig 5)

TABLE 11

Glutamic Acid and Glutamine in Human Brain Samples

	Source		
	Temporal Lobe tomy	Opera on	Au opsy
No of samples	17	1	6
Glutam c acid (mg per cent)	121 7	118 0	168 7
Glutam ne (mg per cent)	48 9	58 7	57 0
Glutam c ac d and glutamine (mg per cent)	170 6	176 7	225 7

Reiner (1947) studied homogenates of rat brain tissue and found low results for embryonic brain and practically unchanged oxygen uptakes throughout the rest of life until old age when a significant decrease was observed in rats over 24 months of age a time which can be taken as the beginning of aging in the rat This work on homogenates of rat brain was repeated by Garbus (1955) employing however somewhat different methods He found a maximum oxygen consumption at 2 weeks of age and equal values both before and after 24 months of age

Using mitochondria obtained from rat brain Weinbach and Garbus (1956) confirmed the results they observed in homogenates namely that there is no decrease in mitochondrial respiration with age They studied oxygen utilization and uptake of phosphorus in the process of oxidative phosphorylation and noted the same rates in brain mitochondria obtained from rats from 3 to 8 months of age and those from 22 to 33½ months of age Does this mean that the oxygen uptake of brain cells *in situ* remain unchanged throughout life a finding which is reminiscent of that obtained by Sokoloff *et al* (1957) for aged human subjects with minimal evidence of disease? It must be remembered however that in vivo we do not have homogenates or mitochondria free of the various barriers which impede diffusion of nutrients and other essential elements Such preparations are suspended in solutions fortified with the various factors necessary to maintain maximal respiration It must also be noted that not all cellular metabolism is centered on mitochondria other systems must also be taken into consideration In minces in contradistinction to mitochondria are found all the elements making up the brain in vivo Homogenates fall in between minces and mitochondria We may therefore suspect that minces approach more closely the brain in situ than do the other two preparations There are significant differences developing among the various cellular elements of the brain with aging Neurons diminish in numbers and their nuclei reveal pyknosis Replacement by glial tissue is variable but must also be considered According to Heller and Elliott (1955) cortical neurons respire more actively than

astrocytes In that case, with progressive atrophy of the cerebral cortex, $CMRO_2$ should decrease too Moreover, the water content of the brain rises during the senium, while that of the solid constituents declines (Burger, 1957) (see Fig 2), changes which tend to reduce metabolic rate on a basis of brain weight But, even if we consider only the decreasing weight of the brain and not that of the solid constituents, we would come to the same conclusion for the metabolism of the brain as a whole We may conclude that the literature on brain metabolism of animals in vitro indicates that mitochondria preserve their full vigor of respiratory activity throughout life This is an important point and suggests that neuronal metabolic rate remains unchanged despite old age In that case the fall in $CMRO_2$ observed so frequently in the aged may be ascribed to adventitious processes usually but not necessarily associated with aging Another possibility is an acceleration of the inevitable loss of neurons, which takes place throughout life There are probably wide differences among individuals in regard to their susceptibility to the adventitious processes associated with aging, as well as the rapidity in loss of neurons Perhaps the apparently different kinds of alterations are not unrelated The observations of Sokoloff and associates (1957),

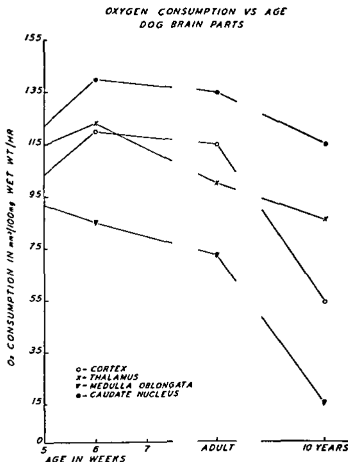


Fig 5 —Changes in metabolism of the parts of dog brain with age The values at 10 years of age are lower than those in a young adult (Adapted from H E Himwich 1951 and unpublished data of W Himwich)

suggest that if the concomitants of aging are present even under optimal conditions, they occur to such a minimal extent that changes in oxygen consumption are not ap parent for the difference between their values and those of younger adults are largely within the area of the method for the determination of $CMRO_2$ In most in stances however the processes associated with aging are more rapid and $CMRO_2$ declines This suggestion of a reduction in oxygen consumption is supported by ob servations on brain minces which contain fects of aging Rabbits, pigeons, and rats have all been studied but not in a complete fashion

Rabbit

In our laboratory we have been attempt ing to maintain a group of aged rabbits These animals are mostly New Zealand whites or albino with a life span of 8 years Graves and Himwich (1955) showed that by 2½ years there was a reduction in total water in the brain from 95 to 77 per cent but that total brain weight was still in

TABLE 12

PERCENTAGE WATER AND NITROGEN CONTENT OF RABBIT BRAIN PARTS

AREA	AGE									
	77 Days (5)*		4 Years (2)		5 Years (4)		6 Years (2)		10 Years (1)	
	H_2O	Nitrogen	H_2O	Nitrogen	H_2O	Nitrogen	H_2O	Nitrogen	H_2O	Nitrogen
Cortex	82 5	1 97	80 9		79 8	2 05	81 3	1 85	73 3	2 41
Caudate	81 6	2 14	79 5		80 1	2 02	79 5	1 96	80 4	2 29
Thalamus	80 4	1 92			77 5	1 74	77 6	1 87	81 7	2 11
Coll culi	78 9	1 90	76 0		75 0	1 97	76 4	1 92	76 2	1 99
Cerebellum										
Lateral lobes	80 0	1 97	78 8		77 7	2 02	78 9	1 98	67 7	2 00
Paraflocculi	80 6	2 02	78 8		77 5	2 11	78 9	1 97	77 3	2 07
Vermis	80 9	2 13	78 3		78 2	2 20	79 9	1 93	78 9	2 36
Medulla	74 6	1 85	70 8		70 1	1 94	71 1	1 86	70 5	1 98
Cervical spinal cord	73 0	1 81			66 7	1 88	69 2	1 65	67 6	1 94

* No of animals in parentheses

the morphological elements of the entire brain and therefore reflect the results of all alterations

IX CHEMICAL ANALYSES OF BRAIN CONSTITUENTS OF ANIMALS

The chemical changes undergone by brain as it develops were first elucidated by the Kochs (1913) in their studies of the brain of the growing rat and pig Our knowledge of the chemical maturation of brain has been further extended by the elegant studies of the Flexners (1955) and of Jordan (1955, 1956) Unfortunately, few research data are available on the ef creasing Our chemical analyses have been done on samples from various anatomical areas rather than on whole brain A com parison of the water content of the parts of the central nervous system shows that all those studied are drier at 4 and 5 years of age than they were at 77 days (Table 12) By 6 years of age all but two parts have shown an increase in water content With out more animals at 6 years and in still older groups it is impossible to determine if this rise in moisture is similar to that which occurs in human brain in the last decades of life But the parallelism with human brain is suggestive It is difficult to evaluate the results on the oldest rabbit

studied (i e 10 years old) This animal showed no physiological signs of aging and was of a breed which may have had a different life-expectancy

The data for total nitrogen in the brain parts are not clear cut In general the values at 6 years are lower than those at either 77 days or 5 years None of the changes is very large It is probable that if whole brain had been analyzed the decline would have been more marked Examination of the human data from Burger (1957) (see Table 4 and Fig 2) for this constituent suggests that in man the diminution of total nitrogen is marked at about the same time as the water content begins to rise in the brain It is interesting that our analyses of parts of human brain (Himwich, unpublished data) have not shown as clear a picture of the effect of age on nitrogen and water as do the results collected by Burger Possibly, the greatest rise or decline in water occurs in parts we have not sampled The change reflected in the entire brain must be the algebraic sum of those alterations occurring in various areas and analysis of a limited number of parts might not give the same result as analysis of whole brain

Pigeon

Koch and Riddle (1918–19, 1919–20) have followed the alterations in the brains of pigeons up to the age of 3266 days If pigeons normally live to an age of 10 years these animals can be considered old The results obtained on these birds are shown in Tables 13 and 14 There is no indication of the achievement of a maximum brain weight and a subsequent decline such as appears to be a constant pattern in man Unfortunately the authors do not give individual results for data other than those of brain weight As the birds age, the water and protein contents of the brain decrease but the extractives and the phosphotid fraction appear to remain about the same In the total protein fraction only is there an indication of a peak in the curve for concentration These maxima occur at 183 days of age The augmentation of lipoids cholesterol and sulfatides tends to parallel the growth in brain weight

The distribution of sulfur and phosphorus in the various fractions is varied (Table 14) Total sulfur tends to rise If pigeon brain can be considered to be like human brain it is possible that *sulfur increases* in old age after a slight fall at 598 days The protein sulfur reaches maximum at 183 days and then falls following the change in total protein (see Table 13) The lipoid phosphorus also shows a peak but at a later time (598 days) The extractive sulfur fraction lipoid sulfur and phosphorus fractions all have irregularities in their rates of increase but appear to parallel brain weight Total phosphorus declines throughout the period of life studied, as does the phosphorus present in protein With the exception of the changes which reflect those in protein these fluctuations may be artifacts

It is impossible to equate these variations with those reported by Burger for human brain Only for brain weight do we have individual data on birds over 3000 days old However these findings and the average figures for the oldest group suggest either that pigeons of nearly 10 years of age are not old physiologically or that their brains age in a pattern different from that of man

Rat

The reports available on the brain of the aging rat are difficult to interpret According to Donaldson (1924), the brain increases in weight as long as the animal grows in terms of body weight body length, and tail length (Table 15) Unfortunately he does not give ages for these animals We can only guess how old a rat with a body weight of approximately 450 gm was in the colony studied by Donaldson at the Wistar Institute However, at 529 days male rats of the same colony had a body weight of 227 gm, so the animals reported for the growth of the brain must have been

But if this diminution becomes further accelerated as suggested by a drop from 81–90 which is sharper than that from 71 80 the brain would fall to half its weight at an earlier period Even though the loss of tissue would not refer to a given area but would be widespread it is difficult to believe that it could occur without marked impairment of mental abilities Accordingly dreams of increased longevity may be disturbed by the specter of senile dementia Prime problems are therefore concerned with the factors which influence the rate of the loss of neurons

These speculations are evoked by the many lacunae in the data relating to aging of the human brain Are there other ways to answer this question of the processes which bring about changes in brain components? Human beings do not live under controlled conditions and it is difficult to conclude whether in an unfortunate individual with brain atrophy the impairment is simply the result of the acceleration of the normal aging processes or due to adventitious insults if only because they have continued opportunity to operate as time progresses Perhaps a decision may be facilitated by observations on a mammalian colony It is true that in animals with a shorter life-span than man a solution may be obtained more rapidly But it should be emphasized that alterations in the brain of aging pigeons rats and rabbits do not duplicate qualitatively or quantitatively the changes observed in humans The ability of rat and pigeon brain to grow throughout life suggests that the brain does not shrink as it does in the human being In the case of the pigeon protein does show a decline in the oldest animals but lipids do not For the rabbit the data available on old animals are confined to brain parts rather than to the whole brain The parts however do not show as marked a change as do whole brains of aged human individuals The thought therefore must arise that a nearer approach to man might be found in the brain of infrahuman primates The more highly developed simian and anthropoid brain should be of greater value in comparative studies with the specialized organ in man But in a way, some of the same problems which complicate the human picture also muddy the animal one How shall such animals be maintained? If we are interested in aging the animals should be protected from undesirable changes such as brought about by stressful situations and disease Animals maintained under such ideal conditions should cast light on the problem of aging per se but they would not reproduce the situations in which human beings live, and again the results could not be applied directly to man This is not to say that animal colonies should not be established for the study of old age On the contrary we are in favor of them because to a greater or lesser degree they should help to disentangle the direct results of old age from complicating factors Extrapolation to man however should not be made without giving heed to differences not only in species but also in living conditions

X Summary

Observations of many subjects, both normal and diseased yield average values for $CMRO_2$ which decrease with age These averages however include observations on healthy old men with $CMRO_2$ at the same level as those of healthy young men Hypertension per se does not seem to cause any definite change but arteriosclerosis is associated with significant decreases in $CMRO_2$ In some instances there are clinical indications of loss of cerebral tissue as after vascular stroke or syphilitic infection In other cases a diagnosis of senile dementia is frequently made But whatever the cause of parenchymal atrophy, whether due to apparent associated disease or to an acceleration of the usual loss of brain cells $CMRO_2$ is significantly impaired Associated with the decrease in $CMRO_2$ are reductions in CBF and corresponding increases of CVR Yet we know the constriction imposed by the decrease of CBF is

not rigid Moreover, the greater CVR is also capable of relaxation Thus we may come to the conclusion that the fall in $CMRO_2$ is not due to lack of essential substrate but rather to primary cellular degeneration, at least in many instances

There are many observations of a reduction in $CMRO_2$ in the literature, some indicating a failure of correspondence between mental changes and fall in $CMRO_2$, while others disclose a parallelism between the two parameters An attempt is therefore made to resolve these inconsistencies by segregating the different observations into two categories In the first category, in which $CMRO_2$ is reduced, are placed acute comatose conditions and senile dementia On the other hand, with the mental aberrations of "functional" disorders, of which schizophrenia is an instance, $CMRO_2$ remains unchanged When "functional' behavioral disorders complicate the clinical picture of dementia, the value for $CMRO_2$ therefore depends on the extent of the irreversible damage to the brain and not upon ' functional ' changes

$CMRO_2$ is a measure of the oxygen consumption per 100 gm of brain and therefore, reveals the intensity factor—the ability of brain tissue to use oxygen The oxygen consumption of the entire brain, or the capacity factor, may or may not vary in the same direction as $CMRO_2$, for example, it is conceivable that $CMRO_2$ may remain unchanged within the error of the method yet the oxygen consumption of the entire brain may decrease simply as the result of loss of brain cells with age Such information is not now available In any event, the present data indicate that any decreases in total oxygen consumption of the brain or in $CMRO_2$ are due to a loss of brain cells rather than to a diminished rate of oxidation of all the cells of the brain But this question cannot be considered as decided

There appears to be no qualitative change in the utilization of foodstuff during aging in man Though the amount of glucose extracted from the blood passing through the brain is somewhat lower in the aged than in younger adults, it is still adequate to account for the total oxygen consumption of the brain

Evidence obtained from the study of the minced brain of animals is not conclusive but is suggestive of the idea that oxygen consumption of the entire brain decreases in the aged With the use of homogenates, the data are conflicting, and one cannot conclude unequivocably that oxygen consumption of brain homogenates continues unaltered throughout life On the other hand, with mitochondria it has been shown that the oxygen uptake of these cellular particulates remains unchanged throughout the life span Yet it must be pointed out that neither homogenate nor mitochondrial metabolism may be regarded as representative of that of the intact neuron, whether on an in vivo or an in vitro basis But the balance of evidence obtained in vitro is in favor of the conception, that the change in $CMRO_2$ is to be ascribed to a loss of neurons Astrocytic replacement, a variable phenomenon produces cells of lower oxygen consumption than those of the cortical neurons Perhaps in the healthy aged men observed by Sokoloff *et al* these processes, which are usually most marked in the aged, were not sufficiently advanced to produce a fall in $CMRO_2$ When however, this loss is less retarded it can account for a decrease in $CMRO_2$ and this applies whether or not individual neurons retain their youthful oxygen consumption or suffer some impairment

It might be expected that the study of the chemical constituents of the brain would add to our knowledge on brain function This statement is true but must be qualified because human brain is seldom obtained in good condition for experimental study Most of the material available is from autopsies, and, even with the shortest time possible before the post mortem examination takes place, far reaching chemical changes have often occurred starting even before the individual was dead These

facts must be considered in evaluating the chemical changes which occur with age

Measurements of the human brain over the entire period of life reveal that the organ attains a peak at approximately 30 years of age, after which it declines in weight Accompanying this loss is, first, a decrease in moisture content during the years of development and, then, an increase in old age Total lipids also fall

The age of 70 was chosen as beginning of the period of senescence, since after this time moisture increases sharply, and total solids and total lipid fall more rapidly than they did earlier The decline in brain weight is also more marked after 70 than it was before this age The values for chemical constituents in human brain after 70 years were compared with those for the period of maturity, that is, 30–70 years of age With the exception of desoxyribonucleic acid (DNA) and sulfur, the various constituents decrease in amount in senescence The actual increase in DNA may be linked to the presence of pyknotic neurons and the proliferation in glia Desposits of sulfur, in the formation of yellow plaques, accumulate in the brain of man starting before puberty and continuing through old age

The chemical changes occurring in discrete areas of the brain are difficult to assess from the data available The problems of the variations in samples from corresponding anatomical areas and differences in the analyses of autopsy material as compared to biopsy samples add to the confusion created by the paucity of data

This review indicates that, among the prime problems of aging, the control of the rate of the loss of neurons may be more important than are efforts to maintain cellular oxidations per se It is pointed out that we should be able to get some help in the study of these problems from observations on animals, but it is also emphasized *that extrapolation to man cannot be made* without much qualification Few comprehensive studies of the brains of aged animals have been made The data suggest that the species of animal used for aging studies must be chosen carefully if the data are to be extrapolated to human brain In the pigeon the brain appears to continue to grow even in old age, namely, 9–10 years for that species Insufficient data are available as yet on rabbit and rat to determine how closely the changes which occur in their brains with age parallel those appearing in man

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VIII

Individual Differences in Constitution and Genetic Background[1]

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I Introduction

Encouraged by recent advances in planned weather control, modern scholars are inclined to believe that man is on the verge of losing one of his favorite topics of conversation With similar strides being taken toward the scientific conquest of aging problems, an important milestone may soon be reached in resolving an equally burning question in human affairs

To be sure there will always be a period of old age to contend with just as it may be assumed that we shall never be without weather With a better understanding of the underlying physical forces however, it is to be expected that both phenomena will be largely divested of their vicissitudinous qualities in affecting man's existence

That genetic studies should be able to make a substantial contribution toward the attainment of this goal with respect to aging may seem rather paradoxical to some students of gerontology While skeptical views of this kind have been somewhat on the decline in recent years, they are still likely to reappear in the form of various allegories and abstractions

Nature Nurture Controversy

Reflecting the vestiges of "a cleavage between natural and social science which really was a cleavage between substance and action body and soul, the objective and the subjective" (Gerard, 1957, p 431), one sided conceptual schemes regarding the roots of human health and survival values are an aftermath of that ill founded debate widely referred to as the nature nurture controversy In the area of aging, this debate is traceable to the old misconception that the effect of heredity, if it is acknowledged at all produces "unalterable finished entities" that are present at birth (Sorsby, 1953) By contrast, aging is often thought of as starting at birth, in itself regarded as "the greatest adaptation process," with aging defined as the concomitant of "a decrease in the capacity for adaptation" (Verzar, 1957, p 60)

Thus, virtually by definition alone, there ensued a peculiar dichotomy between the "static" genetic components of personality and the continuous "dynamics" of such ethnoplastic forces as were considered the basis for all growth and development A corollary was the application of the same

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had a chance to influence each other or enter the same germ cell (law of segregation) It also followed from Mendel s hypothesis that two corresponding genes (alleles) occupy the same linear position on homologous chromosomes

The discovery of these coiled filamentous structures in the nucleus of a cell took place in the 34 year interval during which Mendel s findings remained unnoticed Observed under the microscope as threadlike bodies with a peculiar staining reaction the nuclear filaments were properly identified by Flemming in 1882 and Waldeyer

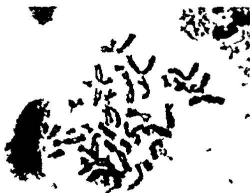


FIG 1 —Human chromosomes (Courtesy of Dr T C Hsu)

in 1888 By means of improved techniques the filaments were actually seen to divide in the process of ordinary cell division and be redistributed as duplicates with each germ cell receiving half the parental chromosome structure This pattern was consistent with Mendel s experimental observations and made it possible to combine the knowledge derived from breeding experiments with that provided by cytogenetic biochemical and evolutionary studies

More precise formulations of the chromosome theory followed as advances in other biological disciplines merged with those made in experimental clinical and population genetics during the first decades of this century

CHROMOSOMES AND GENES

The species characteristics of human populations rest on rigid specifications as to number size shape and relative positions of the original sets of chromosomes found in every cell of the body (Fig 1) It is still undecided whether an ordinary human cell contains 48 chromosomes as had long been accepted or only 46 essential chromosomes plus 1 or 2 supernumerary ones as is assumed at present. It is certain however that the numerical constancy in a species is maintained by reduction to one half the number in the process of meiosis (reduction division) Prior to the division of the cell the chromosomes arrange themselves in an orderly way on a single level at the equator of the cell (Goldschmidt 1952)

Since a species complement of chromosomes and its position on the evolutionary scale do not correspond the modern definition for such an intrabreeding Mendelian population rests on the concept of a reproductive community of individuals who share a common gene pool Accordingly various subspecies or ethnic groups are subordinate Mendelian populations differing in relative frequencies of genes or chromosomal structures and usually also in external appearance and physiological properties (Dobzhansky 1955)

While chromosomes are visible microscopically and have long been known to consist largely of nucleoproteins (substances of high molecular weight made up of proteins and nucleic acids) the original concept of a gene was of a minute invisible protein particle or large molecule situated in a certain segment of a chromosome and distinguished from the molecular structures of adjacent segments by a high degree of specificity of its biochemical action This old construct of a gene has gradually been elaborated into that of a clearly differentiated functional region (locus) which preserves its identity produces a specific effect and is capable of duplicating itself

This self duplication is executed by attracting from the cellular surroundings (nuclear fluid) the raw materials for re constructing the same type of directional center, rearranging and binding them into a pattern identical with its own (Muller, 1956) Because of this unique faculty of genes to construct exact duplicates of them selves and, thus, serve as the synthesized product of chemical reactions that they themselves have directed, genic activity is basic to all reproductive, developmental and aging processes

Chemically, genes have been described as DNA (desoxyribonucleic acid) segments of perhaps several hundred nucleotides which apparently carry the ingredients for the synthesis of a specific macromolecule (McElroy, 1957) The genetic specificity of these primary functional (information al) units is assumed to depend on propor tions and sequences of base pairs in a par ticular DNA segment Replication is prob ably accomplished by separation of com plementary nucleotide chains, followed by synthesis of complementary daughter chains An essential part of this hypothesis is the assumption that the functional proc ess of gene action involves a transfer of DNA specificity to RNA (ribonucleic acid) units which in turn may serve as templates in protein synthesis

With the present balance of evidence pointing to proteins as primary gene prod ucts, it is appropriate to conceive of a mutant gene s effect as the potential cause either of a quantitative deficiency or of a qualitative alteration in one of a multitude of proteins Obviously, one or the other can result in pathological changes (Davis, 1953) By the same token the occurrence of a mutational change at a definable point of a chromosome is sufficient evidence for the existence of a normal allele in the gene pool of the given population The normal gene, even if its biochemical equivalents have yet to be identified, can be assumed to be indispensable in maintaining a well balanced state of physical and mental health

VARIABLE GENE EXPRESSION

With reference to a certain gene, a person is called a "homozygote" if he receives the gene from both parents Under ordinary circumstances he is expected to be consistent in displaying the characteristic effect whereby the gene's presence is usually identified However every gene effect may vary from complete expression to no apparent expression The gene itself merely sets in motion a chain reaction that may be modified by environmental factors, prenatal or postnatal as well as the action of other genes before culminating in the production of a given trait

Subsidiary genes which cause quantita tive changes in the expression of a major mutant gene are referred to as "modifier genes if they contribute to the variable expressivity of a trait Although generally difficult to identify they are called "suppressor genes" if they are responsible for either incomplete penetrance of the main gene or its failure to be expressed at all (lack of penetrance)

Similar principles apply to a "heterozygote who is distinguished by the fact that he received the given gene from only one parent and at the corresponding locus, a different one from the other parent (factor for health with respect to a potentially pathological gene effect) In single factor inheritance only a dominant gene is likely to be distinctly expressed in the heterozygote

In line with classical Mendelian tenets, some genetic characteristics displayed by the heterozygous individual tend to be intermediate between the traits represented by homozygotes In others, the possession of only one member of a gene pair will suffice to produce the given trait (domi nant) while its partner remains unex pressed (recessive) Homozygousness is usually necessary for the expression of a recessive gene in the individual's outward appearance (phenotype), as heterozygousness merely allows the gene to remain part

of that person's genic formula (genotype) to be transmitted to the offspring

Additional variations in the expression of a gene may arise either from the fact that it produces different effects according to its location on the chromosome (position effect) or from a tendency to exert different effects upon various organs from one and the same location (pleiotropic effect) Positional changes may subject the gene to different cytoplasmic influences or make it necessary for the gene to express itself in different linkage groups

Under conditions of linkage, two gene pairs are coupled by the proximity of their location on the same chromosome pair They either tend to be transmitted together or invariably separate Their linkage is closest when the least number of crossings-over occur during the formative stage of the gametes Studies of the frequency of the given genes' separation in the offspring are important for the construction of chromosome maps, as they allow an estimate of the relative chromosomal positions of linked genes

If two genetically determined traits are independently linked to a third set of genes, they provide valuable evidence for the given genes' localization on the same pair of chromosomes In this manner the establishment of linkage between certain characters is expected ultimately to lead to the identification of marker genes for each chromosome pair in man

As a special form of linkage occurring quite commonly, sex linkage is found when the gene for a particular trait is situated on the sex chromosomes (XX in females, XY in males) In this instance crossing over of genes is limited to the homologous portions of the given chromosome pair

MUTATION AND SELECTION

The prototype of genetic change, both evolutional and pathological, may be seen in any mutational process In general, a mutation occurs during gene reproduction either spontaneously or in response to mutagenic agents, but always as an expression of the failure of two synapsed genes to reproduce as exact replicas of themselves The ensuing change may be either structural (change in chromosome structure through deletion, duplication, inversion, or translocation) or chemical (substitution of one component for another or a shift in the order of components)

Depending on whether the mutational change affects a chromosomal point or portion the original biochemical reaction potential will be altered to a lesser or greater extent The consequent deviant chain reaction may be extremely deleterious in its effect (lethal), or moderately severe, or slight and only detectable statistically in large populations by a change in certain health and survival values In any case mutations alter the genotype of the affected person and tend to be transmitted to his offspring It is also certain that the metabolic deficiencies set in motion by a mutant gene effect are due "to changes in quantity, quality, or activity of enzymes, enzyme complexes or other macromolecular systems that undergo specific kinds of chemical combinations and thus cause non random orientations of molecules" (Wagner and Mitchell, 1955, see McElroy and Glass, 1957)

Mutation rates in man occur with calculable frequency and can be estimated in two different ways, both yielding figures which are of the order of 1 in 10^5 (Neel, 1949) The direct method consists in counting the number of affected children born to normal parents in a given population and is primarily applied to dominant mutations The indirect method rests on the hypothesis that, as the reproductive rate is lowered in individuals affected by pathological traits and as the frequency of the particular alleles decreases from one generation to another, this trend may be counterbalanced by constantly occurring mutations, resulting in a hypothetical equilibrium.

In dominant traits this equilibrium is expressed by the following equation

$$u = \frac{1}{2}(1 - f)x,$$

where u is the mutation rate f is the reproductive fitness (frequency of abnormal offspring born to affected persons compared to that of normal offspring born to normal siblings), and x represents the frequency of the abnormality A modification of this formula is used for estimating the mutation rate of recessive genes

In human populations the seventeen traits for which mutation rates are now known tend to mutate with an approximate average frequency of 3 in 10^5 (Neel 1949) Even more important is the fact that the frequency of mutations has been shown experimentally to be increased by such agents as radiation ultraviolet rays, and certain chemicals The practical genetic consequences of these increases, especially those induced by irradiating human populations, are the cause of much current concern and form the basis for intensified investigative work Although exposure to a rising background of radiation has accentuated the need for precise predictions of the anticipated damage it is still 'extremely difficult to extrapolate from increase in mutation rates to the magnitude of the resulting increases in amount of general ill health, or from the fitness of animal populations to the fitness of human populations' (Newcombe, 1957 p 157)

Since mutations are apt to cause changes in adaptedness as well as in gene frequencies they subject individuals to the action of selection a phenomenon defined by Strandskov (1950 p 9) as 'a differential contribution of alleles by one generation

negative, as the ensuing genetic advantage or disadvantage is usually measured in terms of mean family size In any case, the net result of selection always consists in a predictable change in gene frequency, other variables being equal

SINGLE FACTOR TYPE OF INHERITANCE

Where a single mutant gene is potent enough to express itself distinctly against the total normalizing action of innumerable other genes its effect upon the phenotype will be a major one whether it follows a dominant or recessive mode of inheritance or is autosomal (located on any but the sex chromosomes) or sex linked (located on one of the sex chromosomes) in its transmission Hence what typifies the single factor type of inheritance is the tendency of a major mutant gene to alter the structural or functional patterns of phenotypical adaptability to such a degree that its end product is likely to fall into the pathological range of variation

With the non sex determining chromosomes being equally inherited by both sexes autosomal traits are likely to be equally distributed between the sexes Where the expression of such a gene is subject to modification or restriction by the sex specific anatomy and physiology of its carrier the buffered action is referred to as sex limited

In the case of a dominant gene the potency of one member of the given pair of alleles is usually sufficient for the visible expression of its effect in the phenotype of a heterozygote while, for the expression of a recessive gene homozygousness is required In man, however, various pathological conditions fail to conform to this simplified scheme Apparently, some genes are neither fully dominant nor completely recessive but somewhere in between (incomplete dominance or recessiveness), with the degree of expressivity depending "upon the facility with which the trait is detectable in the heterozygote" (Hsia, 1957)

Accordingly, a dominant trait will not be manifested by every heterozygote while a

recessive gene may express itself mildly in a heterozygote whose corresponding factor for health is only incompletely dominant Close study of these modalities promises to be helpful in devising improved techniques for the detection and early treatment of carriers

Simple dominant traits apart from these various qualifications are characterized by transmission in the direct line of descent and by inheritance from one parent Because of the severity of their action they tend to be rare (self eliminating) and are easily studied in pedigrees (Fig 2 *a* and *b*) Since most affected persons are heterozygotes the distinguishing feature of the dominant mode of inheritance as found in Huntington s chorea and probably in certain forms of presenile brain atrophy paralysis agitans and hypertensive disease is once free free forever a fact which has both clinical and social implications (selection pressure)

While the morbidity risk for the children of a heterozygote is 50 per cent (Fig 2 *a*) and that for the children of a homozygote is *theoretically* as high as *100* per cent (Fig 2 *b*) unions between two afflicted persons are most unlikely For the same reason consanguineous marriages play a negligible role in this type of inheritance

If a dominant gene is transmitted on the X chromosome (sex linked) females are more frequently affected than males An affected male has only affected daughters *and normal sons (Fig 2 c)*

In contrast autosomal recessive traits expressed only by homozygotes depend on inheritance from both parents who are frequently only heterozygous carriers and phenotypically unaffected (Fig 2 *d*) No parent whether heterozygous or homozygous for such a trait (Fig 2 *e*) can possibly have an affected child (homozygote) unless he marries another carrier of the given gene Consanguineous marriages are likely to increase the chances of this type of mating especially where a relatively uncommon disorder is involved Transmission along collateral rather than direct lines of descent is the rule

If a recessive gene is sex linked and located on the X chromosome males are more frequently affected than females (Fig 2 *f*) Heterozygous females are phenotypically unaffected as they possess two X chromosomes but half their sons (hemizygotes with only one X chromosome received from the mother) will manifest the trait

To be sure Y borne characters occur only in hemizygous males being transmitted from father to son In the absence of a second Y chromosome there is no room for dominance or recessiveness

MULTIFACTOR TYPE OF INHERITANCE

Barring the operation of sex limited influences equal sex distribution is found in the gradations of normal personality characteristics determined by the interaction of several or many genes In this multifactor type of inheritance cumulative contributions are made by an assortment of genic factors which individually produce only minor variations in any given population These polygenes are neither dominant nor recessive but intermediate and additive in their effects Figure 3 illustrates the expected gradations of polygenically controlled longevity variations in a hypothetical population sample Here the usually observed normal life-span differences (in the absence of lethal factors gross pathological conditions produced by major mutant genes and life-shortening environmental exigencies) are assumed to vary from 55 to 95 years in the male and from 60 to 100 years in the female

Within this range persons with life span potentials between 55 (60) and 65 (70) years have been classified as relatively short lived those between 65 (70) and 85 (90) years as medium grade candidates for a long life and those between 85 (90) and 95 (100) years as long lived in the true sense of the word Sex specific life-expectancy variations which favored the female

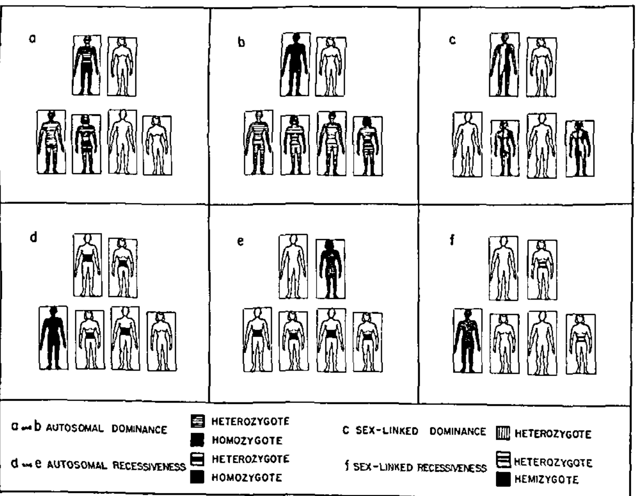


FIG 2 —Single factor modes of inheritance

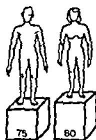
sex by nearly 6 years in 1955, are indicated by a crude over all difference of 5 years corresponding to ¼ inch in the size of the pedestaling blocks used in Figure 3 Pathological gene effects and environmentally produced variations are disregarded and a further simplification of the diagram has been effected by limiting it to a scheme showing only the longevity potentials of the children of two parents with a medium life span range

Since the life span potentials of the offspring tend to be intermediate between

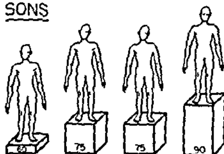
In an intermarrying population with random mating and all varieties of multiple genes for longevity, the distribution of the resultant crosses can be plotted in a bell shaped curve showing variations from the lowest to the highest grades With medium grade persons expected to be in the majority and with the two extreme types the least numerous the total effect will not fall in the pathological range unless placed there either by clinical definition (necessitated by overlapping) or by a mutational change in one of the polygenes involved

MALES

FEMALES



SONS



DAUGHTERS

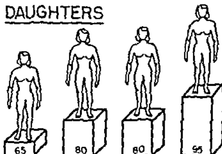


FIG 3 —Quantitative variations in life-span potentials

those of the two parents parental types of this medium age variety result from matings between long lived and short lived persons Similarly the children of short lived parents will be short lived, and the children of long lived parents will be long lived In matings between two medium age parents however, the children are expected to be short lived, medium , and long lived (1 2 1), according to the varying combinations received of the multiple genes potentializing short medium and long life spans

In line with these broad principles of quantitative inheritance (Mather 1949) it is now generally agreed that the list of polygenically determined traits includes the reaction norms of height intelligence, the capacity for survival to an advanced age and variable resistance to selective types of infectious disease Accordingly with the aging process viewed as a concomitant of a varying loss of ability to maintain a constant level of physiological equilibrium during the period of senescence it follows that longevity depends primarily on how

well an aging person withstands the ensuing impairment of health

GENETIC BALANCE PHENOMENA

As for the individual's health and survival values, the potentialities for maintaining them on a satisfactory level are determined by the ability of all genic elements to work together in meticulously co-ordinated reactions, achieving what is called "the balance of the genes" By and large, this physiological phenomenon is analogous to states of physical and mental stability denoted by such expressions as "homeostasis," "adaptiveness," and "emotional equilibrium"

When applied to the genetic composition of entire groups of people (various genotypes), the term "balance" refers to the ideal generation to generation equilibrium in a population whose genetic structure is expected to remain constant under the following conditions (*a*) sufficiently large size, (*b*) random mating (panmixia), with every male having the same chance to mate with any female, (*c*) no selective advantage of one allele over the others at any locus, and (*d*) absence of mutations The cornerstone of a methodical approach to population genetics, this formula is known as the Hardy-Weinberg law, and makes it possible to study major deviations from an equilibrated state, including those based on changes in the balanced interactions of normal human functions so closely related to phenomena of health within a social group

Disturbances in any of the four balancing conditions covered by the Hardy Weinberg law are bound to interfere in various ways with the equilibrium of a population, thereby demonstrating that the continuation of intrapopulation variations from generation to generation are a direct consequence of the simplest Mendelian principles In the absence of a trend toward increasing uniformity, as would be observed either in a "blending" type of inheritance with a consequent reduction of individual differences or in a nonsexually reproducing species, the major causes of modifications in the expected generation to generation equilibrium are limited to assortative mating undersized populations, and the phenomena of mutation and selection

One type of modification takes place as a change in the relative proportions of homozygotes and heterozygotes and does not affect the actual gene frequencies of the population Modifying the phenotypic composition of successive generations by interfering with random mating such a change may be brought about by consanguineous marriage assortative mating and the development of isolates

The second type of modification in an ideal random mating equilibrium is distinguished by the fact that, whenever *selection* operates it has a close relation to the homozygote heterozygote balance of the population and is likely to lead to gene frequency changes Other mechanisms that fall into this category include the phenomena of mutation genetic drift and migration (gene flow)

Genetic drift a potential source of such gene frequency changes, provides a measure of random deviations from ideal Mendelian frequencies Whether operating independently of mutative and selective phenomena or interacting with them, it essentially reflects the fact that Mendelian ratios are approximated rather than ideally achieved in populations of finite size A chance deviation in favor of one allele more probable in a small population rather than a large one, may either lead to the total loss of another allele within a few generations or perpetuate itself in the same direction and result in a new gene frequency (Wright, 1931, 1948)

As to the flow of genes between two intermingling populations (migration), what it accomplishes in terms of the frequency of any gene is to yield a final frequency that is the weighted mean of the two original frequencies Since the frequency of homozygotes varies inversely with the square of population size, the effect of such

intermingling on the composition of the population duplicates that which results from the breakup of isolates

In a system of classification proposed by Wright (1955) for analyzing gene frequen cy changes due to the separate and inter acting effects of mutation selection gene flow and genetic drift the following types of genic equilibrium can be distinguished according to the degree of determinacy (1) neutral equilibrium (*a*) with random mating (Hardy Weinberg law) and (*b*) with deviations from random mating (2) stable equilibrium with selection (*a*) with recurrent mutation (*b*) with heterozygote advantage and (*c*) with more than one environmental niche and (3) unstable equilibrium with heterozygote disadvan tage

While a neutral equilibrium is found in an ideal randomly mating population in the absence of both mutation and selection an alteration in gene frequency under the con ditions of a stable equilibrium is followed by the gradual re establishment of the orig inal frequency The latter type of equilib rium is observed where selection against a certain gene is balanced either by recurrent mutations or by an advantage conferred upon the heterozygote Even if slight this advantage may suffice to maintain an equi librium at which the gene frequencies are entirely determined by the selection coef ficients against the homozygotes (Li 1955 p 259) The stability of this equilibrium can be disturbed by increasing homozygosis due to inbreeding and assortative mating unless the selective advantage of the het erozygote increases proportionally

Another variety of stable equilibrium is encountered when the environment is not uniform but consists of a number of dif ferent local environments (niches) each favoring a different allele If stability is attained with both alleles present the re sult will be a form of balanced polymor phism (Levene 1953)

An unstable equilibrium ensues if the heterozygote is less fit than either type of homozygote and if the two alleles are about equal in frequency With an increased pro portion of one allele at the expense of the other the rarer allele will eventually be reduced to a very low frequency

According to Dobzhansky s balance hy pothesis (Dobzhansky 1955 p 3) hetero zygosity as related to the genetic adapted ness of populations may be (*a*) a *transient* state or (*b*) the result of adaptively neu tral mutants or (*c*) the product of en vironmental diversity while populations would tend by selection to become homo zygous for each of the more advantageous variants of a large number of genes

Hence two main criteria are to be con sidered (*a*) the increased fitness of hetero zygotes (selective advantage) and (*b*) the concept of gene interaction (equivalent to Goldschmidt s chromosomal hierarchy) with a selective advantage of particular combinations of genes If a genic combina tion results in phenotypes best adapted to the environment in which they arise (selec tive advantage) it is assumed that a het *erozygote possessing this coadapted genic* complex will be more fit vigorous and better adapted to the environment than a homozygote This concept which is called euheterosis or overdominance implies that in the process of evolution a number of gene complexes or a set of alleles some how acquired a combined advantage over the single advantages of any one of them

On the level of populations heterozy gous advantage results in a stable equilib rium In this balanced state many well adapted heterozygotes will coexist with a limited number of homozygotes who rep resent a necessary by product distinguished by a lesser degree of *adaptedness* As a trait qualifying the gene pool of a popula tion however such a *balanced polymor phism* tends to confer the capacities both for adaptedness to the present environment

dows the population with its best chance of

survival in the widest variety of potential environments

Health and Longevity Variations in Populations

In a demographic frame of reference no population study of quantitative or qualitative variations in aging and longevity patterns can disregard the widely diversified array of genetic mechanisms without taking the risk of forming misleading opinions as to basic causes Whenever studies of this kind are directed toward relating the frequency, distribution, and patterning of stratifying trends to the life conditions of a group of people, it should be borne in mind that differentiating outside factors react upon individuals who are also members of a population The study of these groups of people affords a meeting ground for the descriptive science of demography and the biological discipline of human genetics

While the primary objective of demographic research is to furnish an inventory of quantitative and qualitative population changes, the aim of genetic studies is to search for the fundamental causes of these changes and their various modes of interaction with physical and social surroundings Only with the genetic basis firmly [illegible]

survival values, one would do well to remember that social factors themselves are the product of evolutionary patterns In the last analysis a chaotic lack of uniformity in human societies is prevented by the fact that ' the cultural forces which mold as well as the formative elements which secure moldability on the human level are actually end products of the same evolutionary process " thus defying separation into independent variables (Kallmann, 1956*d*, p 498)

III Methods and Aims of Genetic Investigation

Exact statistical methods are necessary to evaluate the comparative frequencies of gene specific variations in animals as well as in human populations One of the immediate objectives of any genetic analysis is to determine why and to what extent these values are modified from one group to another Comparisons of this kind provide the impetus for meaningful etiologic investigations

Usable methods in human genetics are rather limited They differ according to whether an analysis deals with the frequencies of normal or pathological characteristics or whether variations of a particular trait are studied in entire populations or certain groups of families (i e, in the relatives of persons distinguished by a pathological condition) In any case, with Mendelian ratios expressing no more than the average expectancy of a gene controlled trait in a representative population sample, it is apparent that only carefully applied statistical procedures can determine the validity of inferences drawn from individual observations (Schulz, 1936 Neel and Schull 1954 Li 1955)

This principle applies to all genetic mechanisms and Mendelian characteristics, physical or mental normal or pathological, common or rare For the sake of conciseness however the discussion here will be limited to those methods of genetic investigation used in studies of aging and longevity

Animal Studies

ADVANTAGES AND LIMITATIONS

The usefulness of animal studies has been established in many areas of geriatric genetics despite various drawbacks from the standpoint of human genetics The main advantages of employing animals rather than human research subjects, according to Bourliere (1957), Calhoun

(1956), Comfort (1956, 1957), Gruneberg (1947), and others (Simms and Berg, 1955, Lansing 1956), are the following

a) While genetic investigations in man are complicated by the investigator's inability to control matings, the experimental geneticist is almost as fortunate as the chemist in that he can assure the purity of his material Working with laboratory stocks that are made genotypically homogeneous through systematic inbreeding (purification of the stock by selecting), he is in a position to study an inherited trait within a pure line Having established the homogeneity of the given condition within his strain he can explore the possibility that similar species characteristics may be derived from different genic elements Crosses between two stocks will indicate "whether the genes responsible are identical or not" (Gruneberg, 1947, p 9) Of course, analogous groupings in physically differentiable human populations which are variously referred to as races, strains peoples, or ethnic groups, bear little resemblance to inbred laboratory stocks

b) While some gene-specific syndromes may be most infrequent in man and even then heterogeneous under a common name or identical under different names, they are "never rare" in animals, where they can be produced in any desired quantity and usually in a very short time (Gruneberg, 1947) In man it is impossible for an observer, within his own lifetime, to study more than a few generations of the same family

c) Since diagnostic and therapeutic procedures require no consideration of the safety factor in the design of laboratory experiments, pathological conditions in animals can be investigated more thoroughly and under far more controlled external circumstances than is possible in human subjects, both in the initial stages and in the progression of the given disease Complete equalization of pertinent environmental factors is unattainable in man

However imposing this set of advantages of animal studies in geriatric genetics may prove to be, it is counterbalanced, either fully or in part, by an equally formidable series of disadvantages, depending on the type of character studied In general terms, these limitations fall into one or more of the following categories

a) Man's existence is unique, so that neither his normal life conditions and aspirations nor his stresses and illnesses are directly comparable to those of animals, either wild or domesticated

b) Optimum habitat preferences are known only for natural subspecies (populations of a species that have come to differ by virtue of isolation and random genetic drift under unrestrained conditions of survival) but not for inbred strains of domesticated laboratory animals from which most of the available research data on aging have been obtained With each species having become adapted to a particular environment conditions of captivity result in various degrees of stress and intolerability because they fail to provide the outlets for action that were present in the native habitat (Calhoun, 1956)

c) Inasmuch as man "possesses certain genes which the laboratory rodents lack," a great number of inherited human diseases have no known close counterpart in the given animal species, and vice versa (Gruneberg, 1947, p 13)

d) The homology of genes in different species can be experimentally established only if "two species can be *crossed*," a requirement which is usually not met (Gruneberg 1947, p 9)

e) There is no experimental mammal, intermediate in size between man and the small rodents, where the rate of aging is actuarially known Apart from an incomplete life table for domestic poultry, satisfactory data on age processes are available only "for man, laboratory rats and mice and a few other small rodents, with partial figures for culled populations of agriculturally important animals" (Comfort, 1957, p 10)

f) Another uncontrolled factor in most animal studies of aging is the effect of

heterosis (heterozygous advantage or hybrid vigor) Here a heterozygous carrier of a gene possesses a selective advantage over either type of homozygote, so that physiological mechanisms controlled by any particular chromosomal locus are expected to achieve the most satisfactory state of homeostasis in the F_1 hybrid In other words, when two divergent genotypes are crossed, the F_1 generation will usually show increased vigor and viability since "*there is greater opportunity that deleterious* recessive genes from one parent will be compensated by dominant alleles from the other parent" (Calhoun, 1956 p 85)

g) Even in animals, studies of aging are costly and difficult to maintain because the number of variables is large and the work is slow" (Pope *et al*, 1956, p 61)

Because of these many shortcomings in the application of animal data on geriatric genetics, the only generalization that can be made at this time is that while functional age changes are found in any kind of animal, different species "apparently do not age in the same way" (Bouliere, 1957, p 29) As far as cellular aging factors are concerned, it is known only that age pigments occur in mammals (including man) as well as in plants, invertebrates, and birds However, whatever information does exist about the actual biological significance of these pigments is highly insufficient According to Lansing (1956 p 7) the available data are still so incomplete that, although they are "consistent with the possibility that aging is an endogenous *mechanism,* *not even this point is* clear"

DIFFERENTIAL LIFE SPAN DATA

Bearing in mind these reservations it may be noted that maximum life span potentials vary widely throughout the animal kingdom, revealing marked disparity even in closely related mammals While the life span of birds often exceeds that of mammals of comparable size and activity (some parrots become centenarians), the life span of smaller vertebrates declines fairly steadily from phylum to phylum in ascending phylogenetic order, with the highest values in fish, amphibia, and reptiles (Comfort, 1957)

According to differential data compiled in Spector's handbook (1956), verified maximum ages in the arthropodal class range from 4 days (house spider) to 45 years (longhorn beetle), in reptiles from 2 years (longtailed lizard) to 177 years (*Galapagos tortoise*), *in birds from 1 year* (swallow) to 64 years (macaw), and in mammals (man excepted) from 2 years (European hedgehog) to 29 years (rhesus), 37 years (chimpanzee) and 57 years (Indian elephant) Obviously, such pronounced differences from one species to another are likely to have a genetic foundation

The much disputed theory of a causal relation between rate of metabolism and duration of life is based on the work of Rubner (1908) and that of Pearl's group (1928) With various mammals using up approximately the same number of calories per unit of weight the smaller species were shown to have a shorter life span than the larger forms Evidently, they have an increased rate of metabolism per unit of weight so as to maintain a constant body temperature In some invertebrates the life-*span could be condensed or lengthened* as the average metabolic rate was raised or lowered (Pearl, 1928)

In Comfort's opinion (1957), however, factors other than the increase in metabolic rates must have been at work in phylogeny to shorten the maximum life span It is well known for instance, that, while the metabolism of small birds as measured by their oxygen consumption is higher than that of rodents it does not tend to decline with age like that of many mammals, although the growth of birds ceases relatively earlier than that of mammals

Bidder's theory (1925, 1932) is that the aging of birds and mammals is endogenous in nature and somehow connected with the evolution of a fixed adult size, which in

turn is attributable to the direct action of a growth inhibiting mechanism evolved during the transition to life on land Be that as it may it has been shown by Mc Cay *et al* (1943) that in rats at least prior to maturity aging and general meta bolic activity are just as dissociable as are growth and development in the tadpole

SEX DIFFERENCES IN LONGEVITY

Within the general area of biological life span differences of apparent genetic origin tancies varied from 67 4 to 73 6 years at birth from 31 8 to 36 7 years at the age of 40 and from 10 5 to 12 4 years at 70 years of age Even in those few countries (i e India and Ceylon) where the male enjoys a slight advantage in his life-expect ancy at birth he begins to conform to the universal pattern as he grows older

There continues to be a wide discrep ancy in explanations of the current mean inter sex life-span difference of approxi mately 6 years Many sociologists insist that the greater life expectancy of women

TABLE 1*

DEMOGRAPHIC AND SEX SPECIFIC VARIATIONS IN LIFE EXPECTANCY

COUNTRY	DIFFERENTIAL LIFE EXPECTANCY									
	At Birth		Age 40		Age 60		Age 70		Age 85	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Brazil (1949 51)	49 80	55 96	25 45	31 21	12 80	16 60	8 34	10 68	3 57	4 49
Canada (1950 52)	66 33	70 83	32 45	35 63	16 49	18 64	10 41	11 62	4 27	4 57
England and Wales (1954)	67 58	73 05	31 49	36 21	15 13	18 83	9 33	11 64	3 97	4 72
France (1950-51)	63 6	69 3	30 4	35 0	15 1	18 1	9 1	11 1	3 4	4 2
India (1941 50)	32 45	31 66	20 53	21 06	10 13	11 33	6 51	7 53	3 06	3 69
Japan (1955)	63 88	68 41	31 15	35 11	15 33	18 59	9 56	12 05		
Norway (1946-50)	69 25	72 65	35 16	36 96	18 39	19 45	11 43	12 03	4 55	4 64
Sweden (1946-50)	69 04	71 58	33 84	35 29	17 05	18 03	10 40	10 89	3 89	4 11
United States (1955)										
White	67 4	73 6	31 8	36 7	16 2	19 4	10 5	12 4	5 1	5 4
Others	61 0	65 8	28 7	31 9	15 7	18 3	11 9	14 0	8 1	8 9
West Germany (1952 53)	64 56	68 48	32 32	34 67	16 20	17 46	9 84	10 42	3 72	4 02

* Source *United Nations Year book 1956*

the understanding of sex specific longevity variations in man has been greatly en hanced by animal studies In human pop ulations it is a well established fact that the life expectancy of the female exceeds that of the male in almost all national and ethnic groups at birth as well as at later ages (Table 1) Global mortality statistics (United Nations Statistical Office 1957) show that a considerable excess of male births is offset everywhere by a lower mortality among females

In the white population of the United States in 1955 male and female life expec

is largely attributable to a more protected station in life with fewer pressures and less likelihood of fatal accidents Whereas a man has to work under more stress in a highly competitive form of civilization modern women are presumed to be consid erably released from the burden of house hold duties by an endless variety of appli ances With the present mortality risks of childbearing greatly reduced in most coun tries women are said to devote much of their time to leisurely living especially as the children reach school age

The spuriousness of such non biological

explanations is demonstrated by the fact that the tendency of the female to outlive the male apparently prevails throughout the animal kingdom (Fig 4) In species where the question of sex specific longevity variations has been studied in detail (Pearl 1922, Hamilton, 1948 Berg and Harmison, 1957), the observed sex differences vary from 2 days in the fruit fly to 51 days in the beetle, 150 days in the rat and 171 days in the spider

These findings indicate that the basic

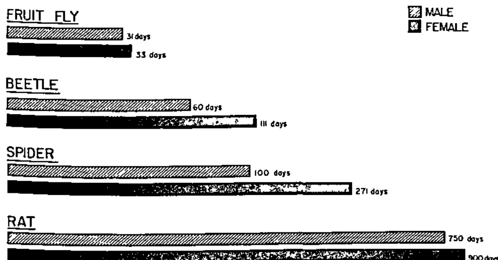


FIG 4 —Sex specific life-span differences in some laboratory animals

reasons for the relatively greater vulnerability of the male are biological rather than social in origin, regardless of whether this phenomenon is ascribed to the male's "an dric components" (*Draper et al*, *1944*), to an androgenically conditioned acceleration of the metabolic rate (Hamilton, 1948) to increased susceptibility to degenerative dis orders (Madigan 1957, Madigan and Vance, 1957), or, perhaps, even to a lack of some genes on the diminutive Y chromosome

That the general biological theory regarding sex specific longevity variations is valid in man, too, has been confirmed by recently compiled mortality data for members of American Catholic teaching orders, 9 813 brothers and 32,041 sisters (Madigan, 1957 Madigan and Vance, 1957) Despite negligible sex differences in occupational hazards and a relatively sheltered life the observed female life expectancy at birth exceeeded that of the male counterparts by about 10 per cent and approximated the female life span values of the general population

Animal studies have been as effective in refuting the theory that the way of life explains the longer life span (lower mortality) of the female, as they have been in demonstrating that the longevity potentials of both sexes vary along with many other species characteristics, genetic as well as non genetic For instance, while it is possible to breed rats or fruit flies for extended longevity potentials, it has also been shown in the latter species (Crowell and Herskovitz, 1957) that the life spans of mated and unmated flies differ in either sex Under comparable external conditions, unmated females live longer than mated ones, while the average life span of mated males is about 10 per cent shorter than that of unmated males (51 0 and 56 8 days, respectively)

IONIZING RADIATION EFFECT ON AGING

Another sector of geriatric genetics where animal studies have been of incalculable value is identified with the life shortening effect of exposure to ionizing radiation There is complete agreement among experimental geneticists (Committee on Genetic Effects of Atomic Radiation 1956 Medical Research Council 1956) on the following points (*a*) Any high energy radiation can cause genetic damage and practically all radiation induced changes are harmful and cumulative (Muller 1954 1957*a* 1957*b* Crow 1958 Trevsky 1958) (*b*) On the whole the life span of irradiated animals is shortened in proportion to the amount of radiation absorbed although the amount of increase in radiation induced mutations varies from one laboratory species to another (Upton 1957 Crow 1958) (*c*) Irradiated animals die prematurely from nearly all causes (apparently due to the cumulative effects of non specific injuries sustained throughout life) and not merely from those causes manifestly related to radiation injury (Comfort 1956 Upton 1957) (*d*) Apart from reducing the length of life of the individuals exposed irradiation may irrevocably affect countless generations of progeny since the effects of an increased mutation rate may be spread very thin over many generations (Hertwig 1938 Russell 1954 Abrahamson and Telfer 1956 Crow 1958) (*e*) In addition to a shortening of the life span the known delayed somatic effects of irradiation include the induction of cataract dermatitis osteitis sterility leukemia and aplastic anemia as well as an increase in

vary with the dose of irradiation received with the sex age and genetic constitution of the animal exposed and even with the age of the sperm cell damaged it may occur in response to the smallest doses (Upton 1957 Crow 1958)

To account for the life shortening action of ionizing radiation the suggestion has been offered that irradiation initiates an additive process of lethal injury incorporating the various kinds of physiological changes produced According to another theory the degenerative processes observed may be due to the deleterious effects of free radicals on protoplasmic constituents Some investigators have even gone so far as to describe all aging phenomena in terms of somatic mutations resulting from cumulative cosmic radiations (Failla 1958) Nevertheless conclusive evidence is still unavailable in this highly complex field What can be stated at this time is that the effects of irradiation on the life span are irreparable and somehow traceable to damage sustained by nuclear cell elements

It is also certain that mutational damage may be spread over prolonged periods of time (with about half the damage occurring only in thirty to fifty generations) and that the most common mutations are those with the smallest direct effect on any one generation (slight detrimentals) rather than those resulting in gross defects (malformations) A mutant that is very harmful is likely to cause sterility or early death (Crow 1958)

GENERAL METHODOLOGICAL PRINCIPLES

In general it may be emphasized that the effectiveness of animal studies in genetics of aging depends not only on careful selection of subjects but also on ability to control their experiences throughout their lives on the part of the investigator (Calhoun 1956) As a rule at least two breeds of the same species should be selected for simultaneous comparative observation One of the major criteria for selecting such breeds rests on clearly defined differences in physiological stability (adjustability to environmental changes) Of course the parameters upon which the environment is modified should have relevance to the abilities of the species and to the behav

tors expressed in the native habitat (Calhoun 1956 p 88)

At present the fruit fly (Demerec, 1950 Clarke and Maynard Smith 1955) and the deer mouse (Dice 1952) are regarded as the two most favorable genera for selecting differing genotypes As to future progress in cellular studies of aging the work of Danielli (1957) in ameba (surgical replacement of the nucleus) and that of Sonneborn and his associates (Ricker 1954 Sonneborn 1954) in paramecium (senescence of clones) seem particularly promising

Investigative Procedures in Human Genetics

While the difficulties encountered in investigating genetic problems of aging in man differ from those of animal studies they are no less formidable A brief review of the general methodological principles involved will be helpful in appraising the varying degrees of conclusiveness of human research data on genetics of aging

PEDIGREE STUDIES

Inasmuch as statistically representative samples of certain subgroups of people or total populations are a principal requirement for any genetic analysis in man observational data obtained from individual families (pedigrees) or sets of relatives (such as one pair of concordant or discordant twins) usually prove of limited value Seldom are family histories published because of familial concentration of superior health and longevity potentials or the rare occurrence of some pathological trait in a particular family Also it is obvious that an affected person would have to be fertile in order to have a similarly afflicted child or that his parents would have to have at least seven children if he is to have six siblings short lived or otherwise

At best therefore the usefulness of the ordinary family history method in human genetics is restricted to verification of individual counseling problems and the study of rare pathological conditions which are easily traced genealogically and are known to be fairly constant in penetrance and clinical expression Apart from demonstrating how often similar varieties of a familial trait may occasionally occur in the members of one family (especially if it happens to be a large one) single pedigrees may serve to show that some family presents features of two or more different syndromes either interchangeably or in various combinations In general however such pedigrees cannot be expected to furnish conclusive proof of the operation of heredity as such nor will they indicate the given mode or modes of inheritance at work

A few examples may illustrate how the pedigree method has been used in gerontology to provide evidence either for the inheritance of longevity (Dublin and Marks 1941) or for that of specific types of presenile disorder In 1934 Pearl and Pearl described a longevous family (Fig 5) using the concept of total immediate ancestral longevity (TIAL) (Pearl 1931) as a yardstick At the time of investigation the male index case was 100 years old with the six direct ancestors also showing an average age of close to 100 years (599 years TIAL) It was emphasized however that some nonagenarians have relatively short lived ancestors

Another interesting pedigree was that of the Hyde family studied by Bell (1918) By classifying the offspring in this family in groups according to their own age at death and the number of those whose fathers had died at age 80 or over it was established that among offspring who survived to the later ages the percentage with fathers attaining age 80 was higher than among offspring succumbing at younger ages Of descendants who died under age 60 only about one quarter had fathers who reached the age of 80 while of descendants who lived to age 80 almost one half had fathers who reached that age (Dublin *et al* 1949)

Pedigrees illustrating either the concurrence of various types of presenile brain

atrophy in one large family or familial concentration of particular forms of this condition were placed on record by Kloepfer (1956) Malamud and Waggoner (1943), and Sjogren et al (1952)

TYPOLOGICAL SYSTEMS

What genealogical studies of individual pedigrees are in analyzing complex genetic phenomena on the family level systems of constitutional typology represent in the area of population genetics especially at the present stage of incomplete knowledge about the basic genetic constituents of aging processes in man It has long been known of course that in any ethnic group people of the same age differ in such general physical characteristics as height, weight and body build It has also been widely noted that obese adults, compared with 'non obese persons, are physically less vigorous and are likely to die at a younger age (Armstrong et al, 1951) Hence many actuarial data related to the total life span have reflected the emphasis on weight, without regard to more specific anthropometric measures On the other hand, body types of small population samples have been described in detail without reference to entire life histories

On the whole, typological systems have been used either in compiling correlations between main types of body build and predominant personality characteristics (anthropometric indexes taken directly or from standardized photographs) or in classifying somatotypal measurements according to the technique of factor analysis (Sheldon, 1940 1942, 1949, 1954, Draper et al, 1944 Rees and Eysenck, 1945, Kretschmer 1951 Kallmann, 1953) The three major body types, called 'asthenic," "pyknic and 'athletic" in Kretschmer's (1951) system and "ectomorphic,' "endomorphic, and "mesomorphic" in that of Sheldon (1954), are shown in Figure 6 In the opinion of some investigators (Rees and Eysenck 1945) measurable physical variation in any human group is largely accounted for by two factors—growth in length and growth in breadth

As to variable longevity potentials, it is interesting that the commonest body type in older age groups is described by Sheldon (1949 1954), as one of "balanced mesomorphic ectomorphy" with a 345 or 354 somatotype (Fig 6) and a tendency to gain no weight (or not more than 17 pounds) in adult life While men with a relatively "feminine" physique are said to have a comparatively short life span, the

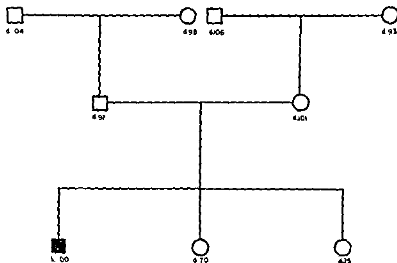


FIG 5 —Pedigree of long lived male (After Pearl and Pearl 1934)

longevous male (octogenarian) is supposed to be of average or slightly under average stature and distinguished by a consistently high textural component (t) This component is measured by a rating on the "physical refinement" (aesthetic quality) of the individual Taking an average for the five regions of the body as a whole, it is gauged to the decimal on a seven point scale (as a "simple linear variable" rather than a multidimensional one)

Apart from the fact that this description of the longest lived somatotype has not been validated by longitudinal studies, it is somewhat at variance with the observation that the life expectancy of normal tall men (exclusive of giants) is as good as that of anyone else (Metropolitan Life Insurance Co 1937) While the life span of extremely tall persons is known to be reduced (in a series of seven men whose height exceeded 7 feet 6 inches, all died before age 45) and the total death rate of tall men (6 feet 2 inches and over) may be slightly increased, it has been shown by an analysis of data in the above study on more than 20,000 tall men that at all ages past 40, the death rates of tall men compare favorably with those of their shorter counterparts

However that may be, no adequate data have as yet been provided to substantiate the premise that a particular body type, or

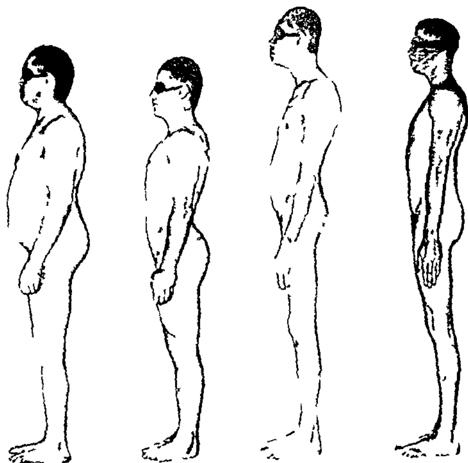


Fig 6 —Main variations in body type. (After Sheldon, 1954)

the relative distribution of constitutional components, or a certain dysplastic variation remains constant throughout a person's life or even during a major part of it What is more, the genetic phenomena responsible for the differentiation of the main constitutional variations, in the period of old age as well as in others are largely unidentified at this point

ACTUARIAL AND CENSUS METHODS

For purposes of a comprehensive genetic analysis the applications of actuarial data be obtained on the distribution of freckles or blood groups (if blood samples are available), on differential mortality trends in different geographical areas or socioeconomic groups, on the effect of precocious or delayed puberty on the life span (Backman, 1948, Jolly, 1954, McCay *et al*, 1956), or on causes of death in certain groups of hospital patients at certain ages

The merits of demographic studies of this kind are illustrated by American life expectancy data (United States Department of Health, Education, and Welfare, 1955) compared in Table 2 according to geo

TABLE 2*

EXPECTATION OF LIFE FOR WHITE MALES AND FEMALES BY GEOGRAPHIC DIVISION

Geographic Division	Expectation of Life (in Years)			
	White Males		White Females	
	Age 0	Age 45	Age 0	Age 45
United States	66 3	26 9	72 0	31 1
New England	66 9	26 6	72 1	30 8
Middle Atlantic	66 2	26 0	71 2	29 9
East North Central	66 5	26 8	71 9	30 8
West North Central	67 8	28 2	73 3	32 1
South Atlantic	66 0	26 9	72 5	31 7
East South Central	66 0	27 6	71 8	31 6
West South Central	66 1	27 7	72 6	32 6
Mountain States	65 4	27 4	71 9	32 0
Pacific States	66 1	26 6	72 9	31 8

* Source *United States Vital Statistics 1949 51*

and total population surveys (census method) are also limited Exceptions are surveys concerned with small and sufficiently co operative populations (isolates), as well as those dealing with relatively uncomplicated traits ascertainable by actuarial or other enumerative procedures (questionnaires, vital statistics, hospital admissions, registries of reportable diseases and defects, differential mortality rates, and the like) Even without close personal contact with the members of the communities to be surveyed, pertinent population data may thus graphic division and by Dahlberg's (1948, 1952) differential county mortality studies in Sweden In the former analysis it is of interest to note that the highest life expectancy in the United States is found in the West North Central States, where a large part of the population is of Scandinavian origin According to Backman (1948), a prolonged life span of Scandinavian people in modern times corresponds to a relatively late average age of menarche

In Dahlberg's study covering twenty five Swedish counties, the northern provinces

distinguished themselves by a consistently higher death rate than prevailed in the rest of the country The difference in longevity was ascribed to the following main factors (*a*) a wilder climate requiring an increased expenditure of energy thereby leading to an earlier onset of aging (*b*) a higher prevalence of pulmonary tuberculosis and (*c*) a larger number of small isolates with a correspondingly high intermarriage rate (also reflected in the high tuberculosis rate) The given increase in intermarriage was assumed to bring about an increase in homozygosis and thus bring together semilethal genes in double dose producing an individual who dies early (Dahlberg 1948 p 158) This life span determining role played by large gene pools and the breaking up of isolates was recently under scored by Larsson (1957)

Whenever specified information of this kind is sought actuarial data and total population surveys will be no more fruitful than in stud es involving possible linkage phenomena or the question of selectivity of some dietary deficiency among the mem bers of certain families Similar limitations arise where longitudinal data are called for or when it comes to genetic problems pre senting difficulties of diagnosis or ascertain ment (reluctance of families to disclose pri vate matters to non specialized research personnel) or questions requiring data on differential fertility rather than general marital rates Finally the application of ordinary census procedures is unsuitable where there is a need for differential mor b dity risk estimates rather than actual prevalence statistics

MORBIDITY RISK DATA AND LIFE EXPECT ANCY CORRELATIONS

When statistically corrected expectancy rates are used the comparative scheme of a genetic analysis is focused either on the ex pected total life span or on the probable or empirically observed morbidity risk of members of certain families with respect to part cular traits and their phenotypical var iations under different circumstances (vari ous periods of time or life changes in eth nic or socioeconomic settings etc) By def inition the disease expectancy of a person is the risk of becoming ill during one s life time if one lives long enough to pass the period of risk that is the time during which the disease may develop (Stromgren 1950 p 157) Morbidity risk data as well as life expectancy rates serve as the basis for refined correlation studies (Larsson 1957)

The two principal methods for obtain ing expectancy rates in clinical genetics are Weinberg s system (proband sibship abridged and double proband methods) and certain extensions of the twin study method (twin family method) Other pro cedures include those of Ilse and Strom gren morbidity tables and Bernstein s a priori method Most of these techniques have been put to extensive use in genetic studies of the major psychoses (Weinberg 1930*a* 1930*b* Schulz 1936 Stromgren 1950 Kallmann 1953)

In Weinberg s system the chief objective of a comparative analysis is to determine whether a given trait occurs more frequent ly in blood relatives of a representative number of probands (index cases disclos ing clinical evidence of the trait) than it does in the general population The ob served number of affected persons among the siblings of the probands (full sibs half sibs step sibs) is analyzed in terms of varying parental matings (affected or unaf fected short lived or long lived)

In the case of full sibs both parents may be phenotypically free of the disease or perhaps long lived For purposes of a ge netic analysis however they would be dis tinguished by the fact of having produced at least one affected (or short lived) child the proband Obviously parental matings with no affected (short lived) child will not be reached by a procedure wh ch begins with a sample of patients of a certain vari ety within the scope of that study This statistical bias in the ascertainment of in dex sibsh ps is corrected by omitting from

the analysis all patients obtained as probands (proband method), while inequalities in age distribution are adjusted in such a way that the observed morbidity rates are converted into average expectancy figures valid for persons who are old enough to have developed the usual clinical symptomatology of the disease entity in question (abridged method) The range of the given manifestation period is to be chosen in accordance with clinical experience

The corrective procedures of Weinberg's system are also used in the twin family method which combines the principles of the proband sibship and abridged methods with those of the twin study method, as well as in the analysis of normal control data for a comparable general population that is a group of persons not ascertained through known consanguinity to the given type of proband (Kallmann 1959 Kallmann and Rainer 1959)

Correlation studies of the genetic aspects of longevity potentials are preferably based on life expectancy rates for representative population samples but have been related mostly to selected assortments of genealogical or insurance records Measuring the correlation between the life spans of parents and their children as well as between sets of children of the same parents several investigators (Beeton and Pearson 1899 1901 Holmes 1928 Stoessiger 1933) obtained rather low correlation coefficients (from 113 to 149) In another study (Wilson and Doering 1926) restriction of the analysis of father son data to cases in which the sons themselves were fathers yielded a considerably higher value (40) The remaining investigations (Howell, 1932, Hunter 1932 Marshall, 1932) depended on insurance records and proved "quite inconclusive either because of the selected character of the material or of the limited number of lives involved' (Dublin *et al*, 1949, p 113), perhaps with the exception of Symonds' study (1913-15), which used the age of grandparents when a living parent was under age 70

TWIN STUDIES

One of the most productive designs for genetic analysis is the twin study method a quasi-experimental procedure which has been profitably employed in exploring the genetics of both normal and abnormal aging patterns Introduced as a genetic research tool by Galton (1876), the method is based on the regular occurrence of two genotypically different types of twins, one egg (monozygotic) and two egg (dizygotic) While one egg twins are always of the same sex two-egg twins may be of the same or opposite sex

In the original version of the twin study method the comparison of observable similarities and dissimilarities in the histories of genetically similar and dissimilar members of a family is limited to twin subjects This procedure requires access to a representative series of one egg and two egg twins of the same or different sex, presenting evidence of a diagnostically or statistically well defined trait or aging criterion to which the principles of the proband method can be applied

For determining the zygosity of same sex twins the method of choice is the modern similarity method with its dermatoglyphic and blood group comparisons (Kallmann, 1953) The fetal membrane method is no longer in use, since it is now known that not all one egg pairs are born with one placenta In particularly important cases where all other diagnostic criteria are indecisive reciprocal skin grafts may be performed

The comparative histories of two typical twin pairs may help to illustrate the fact that one egg twins tend to differ far less in general aging and longevity potentials than do two egg twins or ordinary sibs The twin brothers in Figure 7 belong in the series of two-egg pairs with very similar life conditions (Kallmann 1957) Reared on a farm they attended a rural school together and later became prosperous farmers in the same district In their early thirties each of them married a local girl and had one

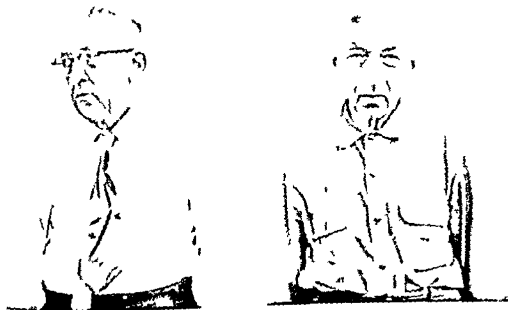


Fig 7 Two egg twins at the age of 23 and 78 years

daughter However despite the similarity of their lives they developed rather disparate personalities and patterns of aging *The younger looking twin on the left* described as prankish excitable and somewhat extravagant complained of ill health for 30 years before retiring at age 70 The *other twin* who still runs his farm on his own at the age of 81 (1958) has always been placid frugal and self sufficient He takes pride in never having seen a doctor except for an appendectomy

The one egg twins in Figure 8 on the other hand remained remarkably alike both physically and mentally although *their fortunes differed to some extent* While one twin was an ordained minister in New England the other was a shoe salesman and lay preacher in the state of New York *Both enjoyed equally satisfac*tory health until they died at the ages of 95½ and 99 respectively

In another version of the twin study *method called the cotwin control method* (Kallmann 1959) observational or experimental data are obtained from a few selected pairs of one egg twins whose aptitudes *metabolic reactions or adjustive po*tentials can be compared under different life conditions or in response to planned differences in management In spontaneously discordant (*one psychotic and one* non psychotic partner) or deliberately dissimilar pairs (one married and one unmarried or one ordained and one non ordained partner) *longitudinal comparisons* of aging patterns biochemical tests or psychometric scores may prove illuminating as to etiology diagnostic classification treatment procedures or personality assessment provided the given twins are monozygotic

The usefulness of this method is illustrated by the twin sisters in Figure 9 now 91 years old Their life histories and personal living conditions differed so much during 47 years of separation that they approximated the widest possible discrepancy imaginable in our culture At the age of 18 the twin on the left in the four photographs married a local farmer She continued to live within a radius of 10 miles from the small rural community where she was born and reared a family of six children *The other twin entered a Bible school* in her middle twenties and soon thereafter went as a missionary to the Orient where she remained until her retirement She was *65 years old when she rejoined her twin* sister who had meanwhile become a widow After 47 years of separation, the twins were still strikingly similar in physical appearance general health conditions, basic personality features and personal interests Without further clues they could not be identified even by means of a long and repeated series of psychometric scores

In the third version the twin family method the comparative scheme is extended to complete sibships of twin index cases and their parents (see Table 4) The six dissimilar sibship groups to be compared are one egg twins two egg twins of the same sex two-egg twins of opposite sex *full sibs half sibs and step sibs* (Kallmann 1953) The main advantages of this procedure lie in its effectiveness as a sampling method and its inconspicuousness as *a pluridisciplinary approach to total popu*lation surveys which require combined cross sectional and longitudinal investigations in a co operative family setting (Kallmann 1957 1959 Kallmann and Rainer 1958) Where it seems both feasible and essential the multiple variance method may be used in this combined procedure to *investigate apparently unitary traits* in the normal range of personality development

Another effective statistical technique employable in estimates of genetic components in normal personality variations is Holzinger s h^2 the variance of two egg twins minus the variance of one egg twins divided by the variance of two egg twins (Kallmann 1959) In order to establish the significance of the h^2 values, an F test may be used for the ratio of the two-egg over the one-egg variance

While morbidity statistics obtained from twin samples are to be related to twin subjects rather than to pairs twin data on

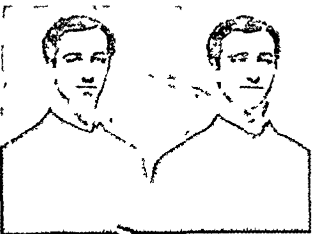
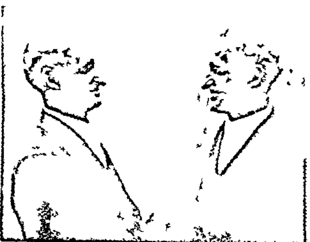
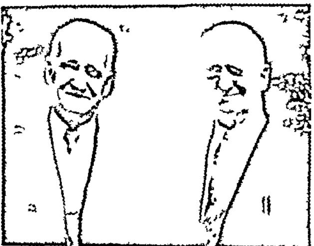





Fig 8 One egg twins at the ages of 5 20 55 and 86 years











FIG 9 —One egg twins before and after long separation

normal personality characteristics are expressed in terms of varying degrees of intrapair similarity or dissimilarity, not concordance or discordance If twin family samples are analyzed in terms of expectancy rates, it is also advisable to compute all statistics from twin index cases rather than twin pairs This requirement applies especially when many pairs are represented by a single index case and when morbidity risk or life expectancy figures are to be compared within the sample

Before concordance rates are finally computed, the number of index cases from concordant pairs may have to be halved in order to correct for the twofold representation of concordant pairs in the sample (Kallmann, 1959) With this stipulation, differences between one egg and two egg groups of twins will have the same statistical significance, whether evaluated in terms of concordance or in terms of morbidity expectancy

METHODOLOGICAL CONSIDERATIONS IN TWIN STUDIES

Like any other research procedure, twin studies have their limitations, if only because twins, as a research species, fall short of perfection Apart from being prone to prematurity and birth trauma, and possible exposure to asymmetrical cytoplasmic influences in the prenatal period, twins cannot be separated before they are born, nor can they be reared in cages What is more, they are destined to inhabit a world in which parents specialize in the practice of bringing up their own children Similar and dissimilar twin partners rarely avail themselves of the chance to separate for the purpose of benefiting from different cultures

To be sure, once a twin has survived his first year of life without tangible signs of organic damage, he is bound to be undistinguished from single born individuals, even to the extent of having a complete ego of his own Just as there is no evidence that premature babies are more likely than full-term infants to develop Alzheimer's disease or a senile psychosis, so are there no statistical indications that infections, emotional disturbances, or early aging phenomena are more prevalent in twins than in the general population

Actually, twins are known to vary as much in their personalities, intellectual performances, aging patterns, and stress symptom thresholds as single-born people Compared with the latter, twins have not been shown by any investigator to be less healthy, less longevous, or less selective in regard to their own formula of adjustment

The popular notion that the behavior patterns of one egg twins are alike chiefly because of unusual similarity in their early environments has yet to be substantiated by statistically representative data If confirmed, the argument would only strengthen rather than weaken correctly formulated genetic theories By the same token, plausible psychodynamic concepts are consistent with the general biological premise that "heredity acts, in part, by influencing the selection, and in fact the creation, of the environment of the given individual" (Muller 1956)

A case in point are the two gentlemen shown in Figure 10 at age 58 Although twins (of the two egg variety), they might easily be taken for father and son, irrespective of their curious legal status as father-in law and son in law through marriage to a widowed mother and her daughter From the standpoint of mate selection, it is of interest that the son in law married first

Thus it has been shown for an impressive array of normal personality characteristics and essential life history data that consistent intrapair similarity does not occur in the absence of genotypic identicalness As to variations in graded health and longevity potentials, it has been demonstrated by many twin studies (Vogt, Wagner, Richner, and Meyer, 1939, Kallmann and Sander, 1948, 1949, Kallmann, Feingold, and Bondy, 1951, Kallmann, 1952, 1956*a*, 1956*b*, 1956*c* 1957, Verschuer, 1954*a*, Kallmann, Aschner, and Falek, 1956) that significant differences are the rule in two-

egg pairs and generally far less pronounced in one egg twins The similarities in the latter group usually extend to the degree of general enfeeblement or its absence, the graying and thinning of the hair the configuration of baldness and senile wrinkle formation the onset and type of senile psychopathology and length of life in general

It is only in one egg twins that even pronounced differences in life experiences are

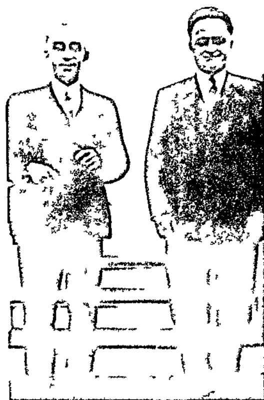


FIG 10 —Dissimilarities in two egg twin brothers

not potent enough to erase basic similarities in physical appearance, personality traits, and general life patterns

IV SERIAL FAMILY AND TWIN DATA ON VARIATIONS IN AGING

For the purpose of bringing the evaluation of comparative statistics on intrafamily variations in aging patterns up to date, only those data based on fairly representative series of families or twins will be considered here As already mentioned, the total number of studies fulfilling this requirement is rather limited

It may also be re emphasized that from a genetic standpoint variations in aging processes fall into three broad categories (Kallmann, 1956*a*, 1956*c*, 1957)

1 The first group consists of polygenically determined gradations in normal aging potentials which produce many small differences in basically positive health and survival values Extreme variations determined in this manner (through the accumulation of short life genes) are likely to produce deviations from the mean health status of an aging population that are classifiable as pathological

2 The second group is formed by specific disorders which cause premature or other severe disturbances in or before the period of old age and may result from the action of one major mutant gene

3 Falling into the third group are gene controlled *deficiency states* which arise before the senescent period and indirectly reduce a person s ability to cope with the stresses engendered by the aging process In this category are the major psychoses, specific metabolic or endocrinopathic disorders and various types of mental deficiency and emotional instability, including schizoid personality traits, compulsive drinking patterns and the like (Kallmann, 1956*c*) While the biochemical correlates of these presenescent deficiencies in adjustive plasticity are still very much in need of clarification, it is justifiable to assume that ordinary aging phenomena tend to be complicated by pre existing maladjustment and intensify it.

Variations in Normal Aging Potentials

That genetic factors determine the total range of normal aging patterns can be demonstrated in various ways The most fruitful studies have been those where intrafamily variations were analyzed with a minimum of uncontrolled variables

FAMILY DATA ON TOTAL LIFE SPAN

A somewhat unorthodox study of family records in Cattaraugus County (Preas, 1945) demonstrated the effect of parental longevity differentials on the filial life span in three classes one where both parents survived to 70 years of age or over, another where both parents died before age 70, and a third where one parent survived to age 70 or more and the other died before 70. The death rates per 1000 at ages 1–49 varied from 4.0 to 8.6 for children born in the period 1850–59 and from 4.8 to 6.9 for those born between 1870 and 1879. However, Dublin *et al* (1949, p 106) point out that "the basic data raise some doubts as to the place of heredity in the picture."

The results of other differential life span analyses related to parental age are summarized in Table 3. The given data were obtained at different times, in different countries, and by means of different statistical procedures (some investigators compared only the life spans of fathers and sons, and the filial life expectancy was computed for different age levels). Accordingly, there were differences in the comparative life expectancy values as well as the size, social stratification, and ethnic composition of the various samples. Yet, in spite of these discrepancies, all studies that were even partly comparable agreed on one point namely, a longer life span for the children of long lived parents than for those of short lived parents.

In *Jalavisto's (1951)* analysis of life-span differences in the members of Finnish and Swedish families of medium and high social status, longevity of the parents (12 786 couples) tended to increase the mean length of life of the offspring. However, maternal longevity was found to have a greater effect than paternal longevity, which in turn had a lesser effect on the life spans of daughters than on those of sons.

TABLE 3

DIFFERENTIAL LIFE SPAN DATA RELATED TO PARENTAL AGE

AUTHOR	LIFE SPAN OF OFFSPRING (IN YEARS)		COMMENT
	Short lived Parents	Long lived Parents	
Actuarial Society of America (1903)	39.44	41.77	Life-expectancy of sons at age 27
Bell (1918)	32.8	52.7	Mean life span of sons and daughters
Pearl (1931)	40.9	45.8	Life expectancy of sons at age 20, related to father's age only
Yuan (1932)	31.5	39.8	Life expectancy of sons at age 20
Jalavisto (1951)	36.2	48.1	Life expectancy of sons at birth
Kallmann *et al* (1956)	45.8	55.2	Mean life span of sons
Kallmann *et al* (1956)	49.5	57.9	Mean life span of sons and daughters

The latter findings were not confirmed by our mean life span data for 1429 senescent twin index sibships (Table 4).

In this study of the life spans of aged twins and their siblings (Kallmann, 1955), the analysis was limited to sibships where there was adequate information as to total survival time of both parents. The ages of living persons were corrected by means of life expectancy tables, and cognizance was taken of the fact that the available sibships were distinguished by survival to age 60 of at least one member, the twin index case. Therefore, our filial life-span data were tabulated in two different ways for entire sibships as well as for the siblings of the twins alone.

Regardless of the statistical procedure used filial life span proved to be clearly related to parental life span Omission of the twin index cases from the computations merely lowered the mean age for the various groups of children without affecting their relationships On the whole, the following trends emerged

1 An important factor differentiating filial life spans is the age reached by the parents whether the ages attained at death by the parents are considered individually or together The highest mean age levels in the sample were reached by sibships when an age of 70 years or over was attained by both parents

2 The differentiating effect of parental age is independent of sex differences and expresses itself in the life-spans of both sons and daughters The total mean life span of the children shows a consistent increase whenever an age of 70 and over was reached by the mother alone, by the father alone, or by both parents

3 While the effects of the ages of fathers and mothers on the life spans of the sons are virtually the same, the life span effect of middle-aged mothers on the longevity potentials of their daughters seems less pronounced In any case, there is no tangible evidence for the operation of a specific sex linked factor in the inheritance of general longevity potentials

The apparent lack of agreement between these data and those of Jalavisto is probably explained by life expectancy differences between the two samples Many of the persons included in the Finnish study lived in the eighteenth century, when 'the many wars and famines which raged in that period' evidently reduced the extent to which parental longevity could affect the natural filial life span

TABLE 4

EFFECT OF PARENTAL AGE ON MEAN LIFE SPANS OF 1429 SENESCENT TWIN INDEX PAIRS AND THEIR SIBLINGS

	Mother Died			Father Died			Either Parent Died			Both Parents Died		
	Under 55	55-69	70 and Over	Under 55	55 69	70 and Over	Under 55	55-69	70 and Over	Under 55	55 69	70 and Over
Twins and sibs												
Sons	55 8	58 8	59 6	56 3	57 2	60 2	55 9	57 4	59 6	51 8	59 6	61 4
Daughters	64 8	60 0	66 4	63 0	64 3	65 3	64 1	62 0	65 7	62 1	59 3	66 8
Total	58 5	57 8	62 1	58 5	60 0	61 5	58 5	59 0	61 8	55 9	59 4	62 9
Sibs only												
Sons	48 6	51 6	52 9	48 5	50 4	53 4	48 5	50 9	53 1	45 8	55 1	55 2
Daughters	55 7	50 8	60 0	51 6	57 5	58 3	53 7	54 3	59 1	54 3	55 8	60 7
Total	51 7	51 2	56 4	49 9	54 0	55 8	50 9	52 7	56 1	49 5	55 4	57 9

The fact that this gene specific effect could be demonstrated at all under the given conditions actually supports the conclusion that the primary factor determining the life span in the filial generation is the age reached by the parents It is, of course, to be expected, and has been fully confirmed by twin studies, that even the finest genetic endowment can go awry, either because of an unusual combination of adverse circumstances, intrinsic or extrinsic in origin, or through prolonged abuse The reverse possibility of making the most of what is there is self evident

TWIN DATA ON LONGEVITY

Serial twin data on aging have been concerned with senile changes of the eye (Vogt *et al* 1939) causes of death (Kallmann *et al* 1955) mental disorders in the aging (Kallmann 1952 1956*a* 1956*b*) and length of life (Vogt *et al* 1939 Kallmann and Sander 1949 Kallmann 1952 1957 Verschuer 1954*a* 1954*b*)

The results of the clinically well documented survey of Vogt and his collaborators (1939) were interpreted in the context of an inherited factor for ocular age changes hitherto regarded as due to wear and tear or to external influences The twin data on causes of death found to be about twice as similar in one egg twin partners as in two-egg pairs of the same or opposite sex (Kallmann *et al* 1955) were necessarily preliminary in nature since there was a relatively large proportion of pairs with incomplete life histories (especially in the cancer series)

Of the two available twin life-span studies the German series (Vogt *et al* 1939 Verschuer 1954*a* 1954*b*) for reasons beyond its control failed to reveal smaller intrapair differences in one egg (thirteen pairs) than in two egg pairs (five sets) The observed mean life span differences were 5 6 and 4 5 years respectively However the 25 year follow up period involved proved to be so calamitous a time in the history of the world that in no less than thirteen of a total of fifteen male pairs compared as to life spans either one or both twin partners (four and nine pairs respectively) were killed in action or ended by suicide The number of pairs in whom both members died of natural causes was thereby reduced to one two egg and two one egg pairs

Hence what this painstaking work largely demonstrated was (*a*) that twin studies are difficult to maintain over a prolonged period of time and lend themselves to interpretation in mystifying terms borrowed from transcendental schools of thought (Kallmann 1959) and (*b*) that life in Germany during Hitler s regime was as unsafe for twins as it was for ordinary people (Kallmann 1955) Subject to a violent death risk of 75 per cent for middle aged men any group of males would be hard put to take full advantage of optimum longevity potentials

In our New York State series of 2536 senescent twin index cases ascertained since the beginning of the study in 1945 the most recent computation of mean intrapair life span differences (Table 5) was limited to pairs where both partners died of verified natural causes after the age of 60 To be on the safe side it was decided that causes of death listed on death certificates had to be substantiated either by adequate hospital records or by detailed reports of family physicians in non hospitalized cases Even unverifiable suspicion regarding the naturalness of one twin s death was enough to eliminate the pair from the present analysis

Moreover the biennial estimates used in earlier computations (Kallmann 1957 p 140) have now been extended to quadrennial ones partly because the 1956 difference between the intrapair life span means of the two male groups although close to 20 months even in this subsample failed to reach the level of statistical significance While the total mean intrapair life span difference was consistently smaller in one egg than in two egg pairs there was an expected disparity between the contributions made by the two sexes to the total difference probably due to the shorter life span of the male

In the 1958 analysis (Table 5) no relevant changes in the general direction of the data have resulted from the modified technique of computing The main indications are as follows

1 The mean intrapair life span differences in same sex two egg pairs continue to exceed those in one egg pairs particularly in the female series The present total mean difference varies from 48 7 months in the one egg group to 66 5 months in the two-egg group

2. In same sex two egg pairs twin partners show similar longevity variations (approximately 5.5 years) in both sexes. The only exception is the small 1950 subgroup of five female pairs with a mean difference of less than 3.5 years (41.3 months) apparently due to the limited size of the subsample.

3. In the one egg series the mean intrapair life span differences in male pairs ranging from 4 to 5 years are consistently larger than those in female pairs (3 years or less).

4. One egg intrapair life span differences show a steady increase in both sexes with the extension of the observational period. In 1958 the difference between the two male subsamples has dwindled to 4.5 months (60.0 and 64.5 months respectively).

Interpreting these longitudinal trends with all due caution it would seem that two opposing effects are discernible in the movements of the intrapair life span differences in our sample. Gaining momentum as more and more twins approach the asymptotic portion of the survival curve, the declining trend is probably due to the inclusion of a sizable subgroup that had a limited life expectancy when it entered the survey. Since approximately one half of the index cases had passed the age of 70 at that time, they had a relatively short period during which they could express genetically determined life span differences. For instance in a pair where the first twin dies at age 97 the cotwin can survive him only for a short time regardless of sex or zygosity. In other words when the longitudinal approach is used the inherent ceiling of the biological phenomenon investigated is likely to obscure the basic variability in such a senescent sample.

Another factor operating in the same direction may be seen in the tendency of a series of two egg twins to show increasing biological homogeneity with advancing age. It is according to expectation that complete pairs of genetically dissimilar (two egg) twins or for that matter, any sets of two individuals who have survived to a very old age at a given time must have been selected for superior health and survival values from a certain point on. With respect to these particular genetic variants, therefore they are likely to converge toward the level of genetic identicalness that distinguishes one egg twins throughout their lives.

Accordingly it was shown in a previous analysis (Kallmann, 1956a) that intrapair life span differences in two-egg pairs were

TABLE 5

QUADRENNIAL MEAN INTRAPAIR LIFE-SPAN DIFFERENCES IN SAME SEX TWINS OVER 60 (BOTH DECEASED)

Type of Twins	Year of Analysis	No. of Pairs	Intrapair Life-Span Differences Expressed in Months		
			Male	Female	Total
One egg pairs	1950	11	48.0	18.2	34.4
	1954	24	50.6	22.9**	37.9*
	1958	41	60.0	36.9*	48.7
Two egg pairs (same sex)	1950	17	73.8	41.3	68.1
	1954	37	68.9	65.6**	67.0*
	1958	45	64.5	68.2*	66.5

Difference between one egg and two-egg pairs significant at 1 per cent level of confidence.
Difference between one egg and two-egg pairs significant at 5 per cent level of confidence.

drastically reduced in the age group over 74 years (32 8 months) when compared to those in the age group 60–74 (101 1 months) In fact, as the corresponding values for one egg pairs remained essentially *unchanged* (37 7 and 34 4 months respectively), the intergroup life span differences became more and more equalized The observed trends will require further refinement of statistical procedures when fully completed life histories will lend themselves to a final analysis of the continuously accruing life span data of this study

When that time comes the opposing factor which may counterbalance this tend

survival, involving the longest period of observation, will exert disproportionate effects upon numerically and biologically unequal groups This factor may explain the observed increase in intrapair life span differences computed quadrennially in the smaller series of one egg pairs Because of the longer life expectancy of the female this effect is expected to express itself at an earlier age in male pairs than in female ones

In retrospect, it may be argued that when this study was organized survival until age 60 should not have been set as a uniform criterion of ascertainment for both sexes Perhaps it would have been preferable to lower the age limit for aging male twins to 50 or 55 years However no data were then available to serve as a guide in determining an optimal lower age limit for this type of longitudinal twin study The age of 60 was chosen quite arbitrarily because it was likely to yield a representative series of senescent twins of either sex whose complete life histories could be observed within the professional lifetime of the investigators

Despite some statistical pitfalls which have been encountered in the interim, it can be stated with assurance at this point that the consecutive analyses of our twin data on intrapair longevity differences have confirmed the gene specific basis for man's total natural life span

LONGITUDINAL TWIN DATA ON DECLINING INTELLECTUAL FUNCTIONS

Regarding measurable changes in the intellectual performance of an aging population it may be noted that cross sectional studies have shown a consistent decline of psychometric scores with advancing age (Miles and Miles 1932, Jones and Conrad, 1933 Wechsler 1944 Doppelt and Wallace 1955) beginning shortly before or during the fourth decade of life and generally more pronounced in performance than verbally (Lorge 1947 Birren and Botwinick 1951 Kleemeier, 1954) However this trend has not been confirmed by longitudinal investigations concerned with changes in intellectual functioning during adulthood prior to the senescent period (Kaplan 1943 Owens 1953, 1955, Bayley and Oden 1955) As a matter of fact, two out of three reports furnished evidence of an increase rather than a decrease in test scores although they dealt with special groups of either gifted (Bayley and Oden, 1955) or intellectually subnormal persons (Kaplan 1943) A detailed discussion of these findings has been given elsewhere (chap xx)

In view of the basic importance of longitudinal observations in this broad field (Bayley 1949, Spence *et al*, 1954, Douglas and Blomfield 1956), especially when it comes to 'general age trends of increment stability, and decrement in any given function (Bayley, 1956, p 151), our psychometric study was planned in such a way as to provide comparable test scores of same sex twins on a longitudinal basis (Kallmann and Sander, 1948, 1949, Feingold 1950 Kallmann *et al*, 1951, Kallmann 1953 1957 1959, Jarvik *et al*, 1957) The genically potentialized nature of major intellectual variations had been previously established for the periods of childhood and adolescence (Feingold,

1950, Jarvik *et al*, 1957, Burt, 1958, Kallmann 1959)

The 300 test cases chosen for the psychometric program in 1947 had to meet the requirements of being white, literate, native born non institutionalized and apparently *free of mental and physical illness* They were drawn from a sample of 1557 senescent twin index cases whose zygosity was sufficiently established to be useful for longitudinal longevity observations With a 13 4 per cent excess of females over males the total number of one egg and two egg index pairs approximated a 1 2 ratio (518 1039) and was in accordance 7 single survivors (from 68 to 87 years old with a mean age of 74 3 years) in 1955, after an interval of almost 8 years (mean 7 8 years)

Although the four subgroups of the original series differed somewhat in age these *differences did not deviate significantly* from chance variations (Feingold, 1950) In terms of sex and zygosity, the distribution of the retested subgroups (1955) approximated that of the original series In both instances the largest subgroup was that of one egg females, followed in order by one egg males two egg females and two egg males

TABLE 6

SEX ZYGOSITY AND AGE OF TESTED SAME SEX TWIN PAIRS

	One Egg Pairs				Two-Egg Pairs				All Pairs			
	First Test*		Retest†		First Test		Retest		First Test		Retest	
	No	Age	No	Age	No	Age	No	Age	No	Age	No	Age
Male	37	69 5	11	74 2	20	70 0	4	74 0	57	69 7	15	74 1
Female	*48*	*67 9*	*15*	*74 5*	*29*	*71 0*	*6*	*74 5*	*77*	*69 1*	*21*	*74 5*
Total	85	68 6	26	74 3	49	70 6	10	74 3	134	69 3	36	74 3

* First test 1947 49
† Retest 1955

with statistical expectation At the beginning of 1958 after 13 years of observation 498 twin subjects were still alive not including 208 pairs where both members survived

Of the original sample only 150 same sex pairs fulfilled the requirements for the testing procedure This series was subsequently reduced to 120 pairs (from 60 to 89 years old with a mean age of 69 3 years) by the inability of some to co operate with the program and was finally replenished (within 2 years) to a total of 134 pairs (Table 6) The first retests with the same battery were administered to 62 pairs within a period of approximately a year (mean 11 7 months), and a second round of retests was given to 36 pairs and

The excess of female pairs (77 female and 57 male pairs) was to be expected in this age range, and the observed increase in the proportion of one egg pairs (85 one egg and 49 two-egg pairs) was probably attributable at least in part, to their relatively smaller intrapair life span differences With one egg life span similarity particularly pronounced in the female sex, such pairs are likely to survive together to an advanced age and thus will predominate in any group of aged unbroken pairs

The battery (Table 7) consisted of four subtests taken from the Wechsler Bellevue Intelligence Test, Scale I (digit symbol substitution block design, similarities, and digit span), List I of the Stanford Binet (1916) vocabulary test, and a simple pa

per and pencil tapping test The comparison of these test data was designed in such a way as to make it possible at the conclusion of the study to evaluate the results in terms of various points of emphasis (the *nature*, *extent*, and rate of change during the senescent period in the particular areas measured, as well as the effect of gene specific factors upon these changes)

For the analysis of longitudinal trends (Table 7), all test subjects were treated as equals, whether they belonged to a one egg or two-egg pair Under this arrangement the 1955 retest data permit a two way comparison The mean raw scores of the sub basis for interpreting the subsequent series of retests

The results of the first test round showed that the mean intrapair differences in test scores were consistently smaller in one egg than in two egg pairs and that the mean scores achieved by twin subjects were fully comparable to those of single born people There was a disparity between male and female intrapair differences indicating that certain intellectual changes in the senescent period are observable in males at an earlier age than in females On the whole, the data revealed that gene specific intellectual variations persist into a well advanced age

TABLE 7

LONGITUDINAL TRENDS IN INTELLECTUAL PERFORMANCE DURING SENESCENCE

Test	No of Index Cases		Mean Scores on Original Tests and on Retests		
	Original Sample	Retested Subsample	Original Sample (1947)	Subsample (1947)	Subsample (1955)
Vocabulary	240	72	28 40	30 74	29 82
Digit symbol	190	67	27 81	29 31	27 75
Block design	206	66	13 39	15 09	12 65
Similarities	230	78	8 85	10 35	9 68
Tapping	240	75	66 10	72 61	56 92
Digit span	239	74	9 98	10 28	9 88

sample of 79 survivors can be compared not only with their own previous scores on the same tests but also with the mean scores of the entire original test group of 240 individuals

The previous test scores used in this comparison are either those obtained in the first test round (1947–48) or where possible the first retest scores (1948–49) To equalize the effect of familiarity with testing procedures upon the results of retests given 8 years later either set of data has been used Both will be referred to as the original score Since the first test retest reliability coefficients for the subtests ranged

In the 1955 retests all six subtests could not be administered to every subject, mainly because of visual or auditory impairment and other physical infirmities manifesting themselves in the higher age groups Consequently it was deemed advisable to tabulate separately the number of tested persons for each subtest

It is interesting to note that the retested subjects did not reach their own original mean scores on any of the six tests (Table 7) The decline was less pronounced on verbal than performance tasks and was statistically significant ($p \leq 01$) only for the latter (digit symbol, block design, and tapping tests)

These findings seem to be unrelated to the fact that, if the raw scores of the four

subtests taken from the Wechsler Bellevue Scale are transformed into scaled scores according to Wechsler s (1944) specifications the mean scores of the retest series are consistently higher than those of the standardization group described by Doppelt and Wallace (1955) In line with their observations there is no evidence of a significant difference between the sexes

As to the rate of intellectual decline with advancing age graphically represented data (Fig 11) indicate that the slope of the curve in our sample during the observed period of 8 years was smaller than that in

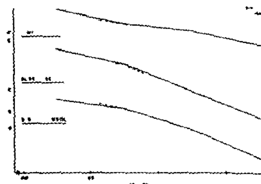


Fig 11 —Longitudinal and cross-sectional data on intellectual decline in senescence

ferred from cross sectional studies Moreover although the mean scores of the twin subjects declined on the whole there were considerable variations from one individual to another While most subjects showed a decrease in score on retest some scored either at the same level or higher

Another noteworthy finding is that the retested survivors achieved higher mean scores on all initial tests compared with the original total test population It may be that these differences reflect a measurable degree of selectivity with respect to biological survival values However since the given differences are below the level of statistical significance they would need verification before this hypothesis could be regarded as substantiated

From a genetic standpoint another highlight of this longitudinal study is the fact that the demonstrability of basic similarities between one egg twins in the senescent period also applied to their measured intellectual performances (Fig 12) Comparison of the test scores of the two zygosity groups reveals that in five out of six tests the trend toward smaller mean intrapair differences was maintained by the one egg series throughout the 8 year period of observation While memory for digits was the function that accounted for the exception the retest series was numerically too small to permit a meaningful application of refined statistical procedures in comparing these subgroup differences

The arrangement of the test scores in Figure 12 represents an attempt to substantiate the hypothesis (based on total longitudinal group data) that unbroken pairs (with two surviving members) may form a uniquely selected segment of the original test series Again the retest data were computed in such a way that the mean intrapair differences in the subsample of 36 surviving pairs can be compared with both their own previous results and those of the entire original series

In 26 one egg pairs there is an increase in intrapair differences which is quite consistent although relatively small and statistically not significant However since similar trends are seen in all six tests the given increase may reflect the effect of incidental concomitants of the senium Such conditions are likely to interfere with the expression of basic similarities in general aging potentials

In the two egg series which consisted of only 10 pairs at the time of the retest intrapair differences tend to be of the same order of magnitude as those in the original sample of two-egg twins However if the comparison is limited to pairs that were available for retesting after 8 years the mean intrapair differences in retest scores are greater than those in the original scores

It is a temptation to conclude therefore that if two-egg senescent twins are to remain testable as a pair 8 years from a starting date they have to be selected on the basis of greater than average similarity in

test performance The data accruing from additional two egg survivors (not included in the 1955 retest series) will afford a first-rate opportunity to test the validity of this intriguing hypothesis

PATHOLOGICAL PROCESSES OF AGING

The genetic analysis of pathological conditions specific to the period of senescence has been handicapped by a scarcity of statistically representative data as well as by diagnostic and terminological problems While family data often are without neuropathological confirmation, there are histochemically verified diagnoses to be found in many case histories that lack complete clinical or genealogical details

Presenile Brain Atrophies

Characteristically, marked imperfections of available case material even persist in that fairly well delineated group of presenile disorders identified by the eponyms of Alzheimer's Pick's, and Jakob Creutzfeldt disease

Although distinguished by an early and rather acute onset, a plainly discernible symptomatology, and, pathologically, by gross and relatively circumscribed cerebral lesions these brain atrophies are not common enough to permit accumulation of extensive family data by any one investigator In fact, so rare is their occurrence in modern populations that it would seem to be in accord with the genetic hypothesis of specific disturbances produced by the effect of single mutant genes (Malamud and Waggoner, 1943, Essen Moller, 1946, Jacob *et al*, 1950) However, some families have been reported in which apparently typical cases of the Alzheimer and Pick variety occurred either together or concurrently with amyotrophic lateral sclerosis, cerebellar ataxia, Huntington's chorea, or senile de-

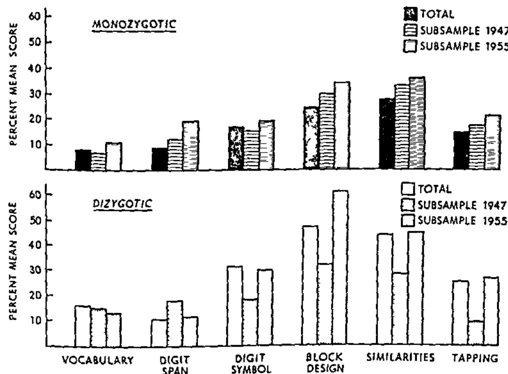


FIG 12—Comparative series of mean intrapair differences in test scores

mentia (Grunthal and Wenger, 1939, Kallmann, 1956*a*, Kloepfer, 1956)

Alzheimer's disease, which is more prevalent and diffuse than Pick's disease, is characterized by a greater frequency of senile plaques (not always present, however) and early thought disturbances (Braunmuhl, 1957), as well as by the fact that in this form the theory of a simple dominant mode of inheritance is less clearly substantiated (Sjogren *et al*, 1952) With an average duration of 7 1 years and an excess of females over males in a 3 2 ratio, the disease reduces the life-expectancy of affected persons at the time of onset (average 53 1 years) by approximately 50 per cent and may vary in its incidence from 1 to 10 per cent of all psychoses of later life (Sjogren *et al*, 1952, Jervis, 1956) The observed morbidity risk figures are 10 per cent for the parents and 3 8 per cent for the sibs of affected individuals

While it is often difficult to differentiate from Pick's disease clinically, Alzheimer's brain atrophy is histopathologically distinguished by the fact that it is rather generalized (as in senile dementia), with some predilection for the temporal and frontal lobes On the whole, the narrowing of the gyri and the widening of the sulci are more severe than the common atrophic changes associated with the senium Microscopically, there is early and extensive neurofibrillary degeneration (usually with an abundance of senile plaques) which is not argentophilic in nature

Compared with the atrophic changes observed in Alzheimer's disease, the atrophy of the brain in Pick's disease is more circumscribed (usually most severely in the frontal lobes) and quite similar to Huntington's chorea in that its affected areas are specific, localized, and selective (Luers and Spatz, 1957) Histopathologically, the condition is characterized by marked cortical gliosis, massive accumulation of lipid material (highly argentophil in character) within the body of the "ballooned" cell, and the absence of both senile plaques and neurofibrillary changes Average age at onset (54 5 years), duration of the disease (6 7 years), and life-span reduction are similar to those in Alzheimer's disease

As to the mode of inheritance involved, the opinions of experts are about equally divided between the simple forms of dominance and recessiveness (Malamud and Waggoner, 1943, Sjogren *et al*, 1952, Kallmann, 1956*a*) Many instances of familial concentrations have been placed on record, including some with direct transmission in three or four generations, or with an accumulation of more than ten cases in one family According to Sjogren *et al* (1952), the morbidity rates for the parents and sibs of affected persons are 19 0 and 6 8 per cent, respectively

Virtually nothing is known about the gene specific metabolic disturbances that may be at the root of these two types of early brain atrophy In the opinion of Braunmuhl (1957), they represent general "heredodegenerative" processes of aging with superimposed mutant gene effects in the colloidal system

Regarding the etiology of Jakob Creutzfeldt disease, the present opinion favors the existence of both hereditary and non hereditary forms Apart from a family with eight affected siblings (Meggendorfer, 1939), the best documented pedigree is that of the Backer family, in which histologically verified cases have occurred in three consecutive generations (Jacob *et al*, 1950)

CEREBRAL ARTERIOSCLEROSIS

Much additional biochemical genetic work is also needed in those disorders in later life in which cerebrovascular changes are the predominant feature As is well known to clinicians, both atherosclerotic lesions and responses to cerebrovascular damage vary from one person to another (Adlersberg *et al*, 1949)

Atherosclerosis, with its marked predominance in the male, is not an ordinary concomitant of aging, some elderly persons of

either sex showing no typical signs of the disease even in their seventies It is a specific disease entity, or, as some investigators believe it may actually be two distinct diseases the first due to defects in cholesterol metabolism or circulatory functions the second resulting from a breakdown of the structure of the elastic elements in the media of arteries accompanied by calcification The increase in deposited calcium has been shown to be associated with an increase in some amino acids which in turn may be related to the action of elastase a pancreatic hormone (Glass 1955 1957)

In line with this theory a tendency toward familial concentration is to be expected and as a matter of fact has been reported for such allied pathological conditions as coronary artery disease essential hypertension and cerebral arteriosclerosis (Wilkinson 1950 Friedman *et al* 1955 Stochdorph and Meessen 1957) It is particularly in the presence of specific disturbances in lipid metabolism known as primary hypercholesterolemia or idiopathic hyperlipemia that such a familial trend has been observed (Adlersberg 1955 Bauer 1955 D Alonzo *et al* 1955 Dock *et al* 1955 Aldersberg *et al* 1956) The genetic hypothesis most frequently proposed is based on a simple dominant mode of inheritance

In the opinion of some investigators a dominant mutant accounts not only for the specific biochemical deficiency resulting in cerebral arteriosclerosis but also for its particular localization (Stochdorph and Meessen 1957) and frequent combination with nephrosclerosis (Sobye 1948) However despite present evidence for a gene specific metabolic error being the basic cause of arteriosclerosis (including hypertensive disease) many important etiological aspects of this serious affliction of the aging are still obscure It is quite possible for instance that the clinical syndrome of arteriosclerotic disorders consists of a number of separate entities each with its specific genetic mechanism (Kallmann *et al*, 1955)

INVOLUTIONAL AND SENILE PSYCHOSES

Caution is also advisable with respect to the theory that the total group of senile dementias may be due to the effect of a dominant genotype of low penetrance (Meggendorfer 1939 Cresseri 1948) It was assumed that either one or two dominant genes were involved one controlling longevity and one producing the pathological changes associated with senile dementia On the other hand many cases showing the symptoms of involutional melancholia were regarded as late manifestations of the manic depressive syndrome

Actually involutional depressions and other non periodic forms of depressive behavior in the involutional and senile periods have been shown by twin family studies (Kallmann 1953 1956*a*) to be unrelated to the cyclic group of disorders Instead increases of involutional psychoses in the families of schizophrenics and of schizophrenic psychoses among the relatives of involutional cases clearly indicate that there is an indirect link with the schizophrenic genotype It seems that the connecting link is formed by persons distinguished by a schizoid type of behavior pattern and that the schizoid personality structure is that of a heterozygous carrier of the schizophrenic genotype with an inadequate degree of general constitutional resistance (Kallmann 1952)

According to this theory emotional maladjustment in the involutional period frequently stems from a decline in adaptability with advancing biological age Along with the cumulative emotional strain arising from increasingly conspicuous signs of aging such typical schizoid traits as rigidity compulsiveness and oversensitivity are likely to result in painful experiences in interpersonal relations gradually overtaxing the adaptive defense mechanisms of emotionally unstable individuals (Kallmann *et al* 1951 Kallmann 1956*c*) The symptoms of the ensuing psychotic break with reality are likely to be precipitated by the

inability to find constructive avenues for releasing anxiety generated by involutional changes

Age specific morbidity risk figures for the relatives of involutional twin index cases (Table 8) indicate that the main trend in these families is toward an increase in involutional psychoses While the twin concordance rates differ from 6.0 per cent for two egg pairs to 60.9 per cent for one egg pairs the corresponding expectancy figures for full sibs half sibs and parents are 6.0 4.5 and 6.4 per cent Apparently persons in the same age group who are genotypically like involutional index cases are most likely to meet the main requirement of an involutional psychosis which is a long standing deficit in adjustive plasticity

As to other psychotic states in the period of senescence twin family data afford even less justification for tracking down a single genetic factor as the basic cause of a senile psychosis (Table 8) Varying from 6.5 to 8.0 per cent for sibs and two-egg cotwins to 42.8 per cent for one egg twins the expected vulnerability to this type of psychosis would seem to arise from an age specific intensification of long existing but minor deficiencies in general emotional adjustment

The most plausible explanation for these data is that the genetic components in the etiology of a senile psychosis consist of polygenically determined variations in age susceptible personality traits, which somehow interact with such genically potentialized biochemical phenomena as control growth and decline Also it is obvious that the capacity for developing a senile psychosis includes the ability to reach the senium without having succumbed to any other type of psychosis or life shortening disorder during the preceding years

From the standpoint of gerontological genetics therefore it may be inferred that prevention of a senile psychosis rests not only on adequate potentialities of emotional adjustment to senescent decrepitudes but also on the establishment of adjustive stability before senescence

TABLE 8

AGE SPECIFIC EXPECTANCY RATES OF INVOLUTIONAL AND SENILE PSYCHOSES FOR BLOOD RELATIVES OF PSYCHOTIC TWIN INDEX CASES

DIAGNOSIS OF ORIGINAL INDEX CASE	PERCENTAGE EXPECTANCY OF THE CORRESPONDING TYPE OF PSYCHOSIS* IN				
	One Egg Cotwins	*Two-Egg Cotwins*	Full Sibs	Half-Sibs	Parents
Involutional psychosis	60.9	6.0	6.0	4.5	6.4
Senile psychosis	42.8	8.0	6.5		3.4

* Related to all persons over age 44 for the involutional group and to all persons over age 59 for the senile group

General Conclusions

1 Despite uncounted gaps in current knowledge about the biochemical correlates of gene specific variations in aging patterns it is safe to state that an effective approach to the behavioral and public health issues of modern gerontology calls for the organization of more genetic research in all phases of personality development including the senescent and presenescent periods of life where the problems are methodologically among the most difficult subjects of genetic investigation Another requirement is the foresight implicit in a concern with the health of the members young and old of future generations

2 Biological factors that are advanta

geous to adjustment to aging extend to healthy and long lived parents full use of genetic potentialities for physical and mental health throughout life and establishment of adequate emotional adjustment before senescence (Kallmann 1956c)

3 While the emphasis in this section had to be placed on the genically controlled factor of change in the human organism it is gratifying to acknowledge that many of the given changes occur without destroying identity As Burwell stressed in discussing time as a fourth dimension of geriatric patients we ought to appreciate that this durable and tenacious organism which is the basis of our life and happiness not only exhibits the fascinating changes discussed but exhibits also a wonderful and vital continuity In the changes imposed by the natural events of life individuality is not lost and our friends are still our friends though they may be old or pregnant or asleep (1958 p 234)

V SUMMARY

The place of genetic concepts in the understanding of individual variations in aging patterns has been described in the foregoing material It has been noted that the current trend in gerontology as in other fields concerned with human welfare is toward increasing recognition of genetic principles

In brief the body of information contributed by genetic studies in man was presented in the following way

1 *Introduction* —In the area of aging the ill founded nature nurture controversy is traceable to the old misconcept on that the effect of heredity produces unalterable finished entities that are present at birth Actually the processes of aging are as much part of the total development pattern brought about by genes as are growth and organ formation

2 *General genetic aspects of variable health potentials* —Considered in terms of the individual the potentialities for maintaining health and survival values on a satisfactory level are determined by the ability of all genic elements to work together by establishing a meticulously co ordinated balance of the genes When applied to the genetic composition of entire groups of people the term balance refers to the ideal generation to generation equilibrium in a population

In a demographic frame of reference no population study of quantitative or qualitative variations in aging and longevity patterns can disregard the effects of genetic mechanisms without taking the risk of forming misleading opinions as to basic causes which genetic research aims to explore The prototype of genetic changes both evolutional and pathological is represented by mutational processes

3 *Methods and aims of genetic investigation* —With Mendelian ratios expressing no more than the average expectancy of a gene controlled trait in a representative population sample exact statistical methods are necessary to evaluate the comparative frequencies of observable variations in animals as well as in human populations In weighing advantages and limitations of animal studies in gerontological genetics particular emphasis is placed on differential life span data in the animal kingdom sex specific longevity variations and ionizing radiation effects on ag ng

Among the investigative procedures in human genetics are ped gree studies typological systems actuarial and census methods morbidity risk data and life expectancy correlations and the twin study method Twin studies are based on the regular occurrence of two genetically different types of twins one egg and two-egg and are applicable in three different versions (*a*) the twin study method proper (*b*) the cotwin control method and (*c*) the twin family method

4 *Serial family and twin data on variations in aging* —The gene specific basis of variations in normal aging potentials has been demonstrated by twin family and general population studies and by comparing the life spans of senescent index sib

ships with those of their parents Twin data show that, in pairs where both members died after age 60, *the mean intrapair life-span difference is smaller in one egg than in two egg pairs* thus confirming the genically *potentialized foundation of man's total natural life span*

The demonstrability of basic similarities between one egg twins in the senescent period also applies to their measured intellectual performances As to the rate of intellectual decline with advancing age, longitudinal observations in twins indicate that the slope of the curve is smaller than what has been inferred from cross-sectional studies

The genetic analysis of pathological conditions that are specific to the period of senescence has been handicapped by a scarcity of statistically representative data as well as by diagnostic and terminological problems Therefore, current theories regarding the genetic aspects of presenile brain atrophies, cerebral arteriosclerosis, and involutional and senile psychoses still lack verification

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IX

Aging and Organization

R. W. GERARD

This chapter is intended as a discussion of the special problem of aging of complex systems Little literature has been cited because as yet there is little literature to review As a thought piece about an area not well explored it is designed to give some substance to an important topic and to provoke conceptualization and experimentation An emphasis has been given to the role of the nervous system, but this needs no apology, since the nervous system is the prime integrator of a complex organization It is difficult to conceive of a complex organization such as man existing without an efficient specialized integrating system Certainly aging of the nervous system has consequences for functioning of distant cells and tissues as well as behavior and indeed for the very existence of the individual organism

I Systems

"An animal is something that happens," and an organism is an event extended in space and time At any instant, a cross-section in time's flow, an examination of the organism would reveal its architecture or morphology or state of being Those patterns of its components which reappear fairly regularly in different time sections would constitute its anatomy The kinds, numbers, and spatial arrangements of the units and subunits of the organism give the structure

An ongoing organism is not encompassed by its architecture of being, it also functions or acts or behaves Such behaving is associated with a change in architecture during the action, but the system then reverts essentially to its prior condition when the behavior is completed Behaving is thus a reversible change along the time axis, so far as the organism is concerned, the consequences of the behavior it emits are commonly not reversible The great bulk of routine automatic behavior, the two thousand steps of a mile walk, certainly leaves the actor little different, but this is probably never completely true even for automatic behavior and is often quite false for innovative or creative or novel behavior, which leaves material traces in the organism lasting a shorter or longer time after the action

The irreversible secular changes in an organism in time, its longitudinal cross section along the temporal axis, describe its evolution or development or history or becoming and complete the triad of the major attributes—being, behaving, and becoming —which apply to all systems

What has been said for the organism applies equally well to an organ as a subsystem of the organism and to a cell or a molecule as further subsystems It also applies to a group of organisms, as a family or a herd or a community, of which the individual is now a subunit, and to still larger systems, as race and society or ecosystem, of which the group is a subsystem If the levels, from molecule to society,

are placed along a vertical axis and the attributes along a horizontal one a table is generated the cells or boxes of which form convenient pigeonholes for the find ings of science This system s approach has been developed extensively and promises usefulness in connection with the problems of aging

It has often been urged that structure function and development flow into one another This is surely correct but it does not follow that the divisions are meaning less The performance of a function de pends on the structure available but the structure in question is not primarily at the level of the function but at one level down the hierarchy Thus the contraction or shortening of a muscle depends on the existence of longitudinally oriented muscle fibers or cell groups the shortening of a muscle fiber depends similarly on longi tudinally oriented muscle fibrils and mi celles and the shortening of a muscle m celle depends on the spatial arrange ments of the component molecules and the r atomic subgroupings If we inquire further as to how these structures arose

miceller level just as muscle fibers were laid down by processes at the molecular and then atomic levels Behaving of the whole muscle thus depends on the being of the muscle cells and this depends on the becom ng of the muscle molecules

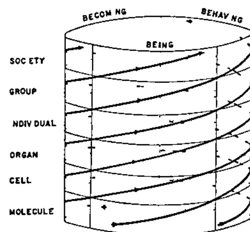
The same relations clearly exist at all levels of the hierarchy The voting be

groups The performance of a team depends on the relations and attributes of the in

—receptors muscles and brains In fact the whole picture is perhaps most clearly represented (Fig 1) by curling the flat table into a cylinder A family of spiraling lines then shows the ascent along the levels from becoming to being to behaving These viewpoints are fully developed elsewhere (Gerard 1958) and have been applied spe cifically to the aging problem in a recent symposium (U S Veterans Administration 1959)

II Irreversibility

All systems change with time On man s time scale a match burns rap dly and the



sun slowly but the earth or the galaxy carries with it into the present sufficient indicators of its past so that man decipher ing these can make reasonable guesses about its age and history A given entity is by definition older at a later instant of time than at an earlier one but this does not necessarily make it more aged (See chapter ii for a more complete discussion of the properties of time) In the vast ma jority of cases a system acquires its greatest energy and organization at the time of for mation and for the rest of its existence loses these as entrophy rises and heteroge neity drifts toward random mixed upness Living things notoriously have an earlier

phase of increasing differentiation and growth during which energy and organization increase prior to the more orthodox decline Perhaps it is not the problem of aging or senescence that requires special attention in living organisms but rather the problem of development and evolution that tends to set them apart This earlier phase does however have significant repercussions on the later one

The striking fact about the development of organisms whether the embryology of the individual or the evolution of the phylum is the increase in organized complexity This necessarily involves a series of regulated and interacting processes occurring in proper sequence quantity and locus The more intricately organized the final product the greater is the number of processes involved in producing it and the smaller the permissible tolerance of error especially in the earliest of these Despite the best of homeostatic controls the developing system will veer a bit from the straight and narrow path as it (or its subsystems) is now and again exposed to the vicissitudes of environmental accident Each organism is thus the product of its particular past and the more complex it is the more does it carry an individuality based upon its built in history Even in the evolution of species the completely accidental event may be decisive (Wright 1948) certainly the more elaborate the development of an individual the more dependent it is on its own past

Not only does the complex organism possess a greater individuality as a whole it also possesses greater differentiation of the parts or subsystems These organs or cells or cell organelles have also experienced their particular developments and have differentiated in their various directions and by virtue of a past that led cells to form liver or lens they can no longer become gut or brain The specialized units lose their totipotency and depend on the support of their fellows specialized for other functions This progressive specialization with differentiation of the units and their consequent tighter reintegration and coordination in the whole is the basic change of organic development This is no less true for social organisms in their interactions and products as a group than it is for the individual organisms or their parts in fact because such higher level systems are even more complicated than the individuals composing them epiorganisms are even more dependent on the regular or unique events of their past than are the organisms composing them

Building even maintaining organized heterogeneity requires an infusion of energy Static systems lacking this after their formation steadily erode or decay and finally vanish Living things in dynamic equilibrium feed on outside energy and substance and so can seemingly violate the second law of thermodynamics during development and maintenance The haunting question then becomes Why does such a vigorously feeding system still with plenty of fuel available slip from the positive to the negative side of the balance and finally run to ground as do non energy using systems? The answer seems to be limited to either (1) a loss of some initial organization which seems highly improbable in view of the unlimited recycling of the generations and the continuing directional change of evolution or (2) the accumulation of hampering materials or patterns Such secular and relatively irreversible changes must constitute the heart of the aging process

It is obvious yet perhaps requires note that aging (or any enduring change) occurs only in a material system There is no such thing as an old nerve impulse there is only a new impulse in an old nerve Even an old organization which differs from a young one in the established lines of communication depends on material objects (buzzer or address systems) or on individual humans who have acquired certain behavior patterns and accepted certain roles (in turn dependent upon material changes in their nervous systems) If the material entities are destroyed so is the

organization, if parts are replaced, human or other, adjustment and learning are required of the new elements From enzyme to ecosystem, becoming involves a progressive change which is irreversible under the ordinary conditions of existence of that system And for a system at any given level this involves a change in its units or subunits—a change in the number or proportion of each kind of unit or a change in their spatial distributions

III Aging

A system might be considered as built of a population of its units—a community built of men, men of cells, cells of molecules The old entity will differ from the young one, in the simplest case, in the proportion of units of various types An old society will have a larger proportion of the kind of individual we call "old" than will a young society This is equally true for a cell and its molecules, where "old" molecules are those which appear in larger quantities with the passage of time The aging of wine or spirits is just such a process, free acids and alcohols are gradually replaced by fragrant esters, and an increase in the percentage of these molecules confers the desired properties of age Aging of connective tissue may similarly relate to an increase in dicarboxylic acids in the proteins, their combination with calcium etc (Lansing, 1955) Aging in metals, on the other hand, seems to involve less a change in proportions of components than in their positions The metallic species separate into sharper and larger crystals (no violation of the earlier statements regarding organization since energy is lost in this process), which in turn, produces easier cleavage planes and weakening Rejuvenation in such a case is achieved by remixing of the molecules or atoms as by melting—suggestive of the endomixis which gives protozoa their immortality and perhaps also of the action of starvation on some metazoan life spans (see also chap iv)

In every change of state of a system with time there is some sort of change in its components but not all these are called aging certainly not senescence The problem and it is a separate one for each level and for each system in each level, is to identify the particular changes in substance or organization that are critical to the altered performance—and surely we are concerned primarily with performance—of the entire system In general, however, the changes of aging will involve a decrease in reactivity of the system, as in substituting ester for acids large crystals for small ones, well worn paths for uncertain and variable ones and as a consequence more routine and habitual for novel or innovative behavior The cumulative accidents of individual experience help produce a more unique system and also inevitably lead to the accumulation of particular defects in its functioning

The higher the level of the system, the more interdependent units and subunits of which it is composed the more striking will be the progressive interference with function as these accidents and failings accumulate Small changes in the structure of a unit can lead to big changes in the performance of the whole under these conditions and in general the more highly integrated functions are more vulnerable to the artillery of time than are the simpler ones Behaving is more critically dependent on being at the higher levels than at the lower ones a small change in state leading to a great change in performance This is true for drug action, fatigue, oxygen deprivation etc, at the level of organisms, it is true for aging at all levels. A nut or a bolt may age negligibly over years, yet the nut and bolt age greatly Small nicks on the thread (a change in location of components) or minimal rusting (a change in proportion of components) can make it impossible to screw the nut on the bolt and so lead to a functional breakdown In this case also, a little "endomixis" can rejuvenate the system, with minor nicks or rusting, screwing the nut forcibly onto the bolt will restore full function The rou-

timizing of internal responses and the canalizing of communication paths (perhaps by actual growth of neuron end feet), likewise, make for good habitual responses but poorer adjustment to novel or more demanding situations Complex systems are, therefore more likely to age than are simple ones because of the greater number of individual links that might fail, loss of proper meshing between the several links or parts, failure of regulating mechanisms, and disturbance of the information channels

The general argument to this point puts aging in the following perspective All systems tend to run down in time except those which feed on outside resources, as do living organisms These build up during development but still ultimately run down, not from the exhaustion of an initial material or pattern but from the accumulation of some untoward substances or arrangements In the simpler systems a kind of stirring up may suffice for rejuvenation, in the more complex systems, with a hierarchy of specialized and interdependent units and subunits, there is a high order of individuality produced by inevitable and accidental events in the history, and most of these (like mutations) are detrimental The more complex the organism or system, the greater will be the deficit in performance of the whole resulting from minor damage to the parts Aging is a description of this general decay with time most characteristic of the higher functions of the higher organisms, depending on different particular key mechanisms in particular cases but universal in its general impact

Molecules age by atom or radical replacement, by polymerization, and the like With more "old' molecules in protein fibers, there is 'aging" of the mineral content, of fixed charges and hydrogen bonds of parallel versus irregular orientation, of alignment or slippage, etc There is aging of the micelles and colloids built from these macromolecules and lesser ones—in size, composition, and distribution of the emerging cell organelles There is aging of cells, as the attributes of such components alter, with attendant changes in rates of change—in metabolism, in diffusion, in contraction or secretion, in irritability and speed of response, and the like Organs age as the cell types and numbers that compose them are altered and as the connections and channels between these change, so that vascular tubes become rigid and narrow and neural pathways become fixed and unalterable The old individual, in consequence, exhibits rigidity of performance with repetitiveness and slowing, and the group with well grooved roles and communication channels, similarly falls in to habitual performance patterns In each case, rejuvenation, with or without duplication and reproduction, is associated with some sort of stirring up of the system and breakdown of the fixed patterns This, more than the change in quantities of materials, seems the most critical factor It is not profitable therefore, to seek a regression of causes leading say to the loss of some critical enzyme for such a loss would indeed be ultimate and permanent, whereas life somehow always does lift itself again from the decline of age

IV Mechanisms

What is profitable is to seek at each level the particular subsystem which is most critical to the aging of the whole Thus, at the molecular level, changes in macromolecules and their water and ion binding properties seem of special importance The resultant changes in collagen and elastic tissue are perhaps the critical elements at the cellular level, those involving fibroblasts presumably being most important These in turn lead to key changes at the organ level in the cardiovascular system which is so critical in the aging of the whole body Performance of the individual, however, certainly at the human level, depends more critically on changes in the nervous system and almost certainly on the patterns of neuron interaction more than on changes in the neurones as entities

Finally, at the group level, the problem of the aging man is that of loss of a functioning place or role in the ongoing business of his community—the aged survive better in primitive societies, where they have a role to play and social status, than in our society, which shelves them (Comfort, 1956, p 194) (The community, however, ages in terms of increasing age of the leaders and, like fixed patterns in the nervous system, from overly channelized communication networks) In all cases nonetheless, one sees aging as a loss of speed and flexibility, the establishment of more rigid patterns of structure and performance, and the breakdown of integration or homeostatic processes

The general approach to aging or senescence that has been developed so far has at least the advantage of subsuming most of the more particular views regarding aging, whatever its virtue or failing in pointing a quantifying finger to the critical factors Comfort (1956), in the introductory chapter of his *The Biology of Senescence* (pp 7–8), condenses the theories of senescence, dividing them into "fundamentalist' theories which regard it as some inherent property of living matter or cells and "epiphenomenalist" theories which attribute it to particular systems or conditions In the first group he places cellular wear and tear, colloid deterioration, and inherent running down of tissue—nervous, endocrine, vascular, or connective In the second group are toxin production, metaplasm accumulation, cumulative damage of radiation, running down of a fixed energy store, depletion of materials, and cessation of growth Later (pp 162 ff) he summarizes mechanisms under the headings (*a*) 'senescence in cells," including irreplaceable enzymes, cell turnover, somatic mutation, and specificity, and (*b*) 'endocrine senescence,' including general, gonad pituitary system, and hormonal regulation of growth in vertebrates Or, on another cate individual and environment and consequent specializations

V Integrative Decay

The effects of radiation, seen by many as equivalent to aging, exemplify well the greater vulnerability of complex over simple systems Single molecules require very high roentgen dosage to show damage, enzymes, less so Viruses are generally interfered with at lower levels, then come bacteria protozoa, and the more primitive invertebrates Vertebrates tend to be more sensitive and mammals more so than fish or amphibia A social group is upset by even smaller doses of radiation—witness the commotion attending any actual or anticipated increase in ambient radiation

The same sort of story unfolds for inanimate systems of all sorts, subjected to environmental attack of miscellaneous types Dust, moisture, mechanical, shock, temperature extremes, and the like are more damaging to the complex than to the simple systems, indeed, without any deliberate application of these traumas, the more complex entities show a higher degree of 'senescence' than do the simpler ones A test tube ages little with use, an automobile much A fine instrument, as a watch, requires more protection from its environment than does a coarse instrument of the same type A cotton thread changes slowly with time, a cotton fabric more rapidly and a cotton garment develops an intolerable degree of pathology and goes into the discard relatively quickly

It is important to note, in these instances that aging still involves the separate levels as such Glass, especially in strong light, does slowly age even without handling Glass in the form of a test tube ages more rapidly, owing to greater environmental attack and to more precise demands on the object, as a form as well as a substance Left alone, iron tarnishes or rusts subjected to mechanical deformation, it further crystallizes, in an automobile engine it is worn away rapidly, in

bearings iron cannot be tolerated because of rapid deterioration

The homeostatic mechanisms—endocrine autonomic, circulatory—that integrate and regulate the multicellular animal have been extensively examined in relation to age, and, in general, a decline in their speed and power has been found (Shock, 1955, Comfort, 1956) Comfort well says (1956, p 189) "As the contribution of successive age groups to the next generation of progeny is reduced by natural causes, so the selection pressure declines, and the efficiency of the homeostatic mechanisms with it The organism ultimately dies of old age because it is now an unstable system which is provided with no further sequence of operational instructions and in which divergent processes are no longer coordinated to maintain function" This, despite the regular finding of severe pathology in the senile body (Cameron, 1955) Organic senescence and death follow along these lines, behavioral or social failure depends primarily on the central nervous system

VI The Nervous System

Perhaps the best exemplification of the greater vulnerability of the complex over the simple, and certainly the one of greatest interest to anthropocentric man, is that afforded by the nervous system and behavior None but the fatuous romantic denies that man's abilities and performance decay with advancing years, yet it has proved singularly difficult to relate this to any concrete structural or functional alteration in the nervous system and its attached organs Because of its special importance to behavior, selected aspects of aging of the nervous system are discussed here For details of the characteristics of the aging nervous system readers are referred in particular to chapters v, vi, and vii

Old nerve fibers conduct at least as rapidly as do young ones, they show no rise in threshold, fall in action potential, or rise in refractory period (Birren, 1959) A slowing of fiber regeneration, reported by some (Windle, 1959), has been denied by Moyer (1959), who also rejects any loss of neurones with aging Others have pointed out that a constant neuron count still means a considerable decrease in number (Schulze, 1955), since total brain weight is down a sixth or more in the aged (Burger, 1954), but Moyer finds an undiminished number of spinal root fibers in old animals

Changes in the rate of biochemical processes have also been reported, and denied, as a function of age Brain Q_{O_2} has been found, when disease conditions are carefully eliminated, to be as high in old men or animals as in young ones (Kety, 1956, Sokoloff, 1959), but the total oxygen consumption of brain must nonetheless be down, since brain size is decreased (see chap v, p 137, and chap vii, p 194) A decreased nucleic acid content has been reported in old neurones (Hyden, 1952) but has been denied as strongly (Lowry and Hastings, 1952) A large fall in inorganic phosphate in the old brain is claimed, along with some increase in sodium and sulfur and a fall in potassium (Himwich, 1959) The general finding of increased calcium and magnesium with age is denied in the case of the nervous system (Streicher, 1958) The old brain is reported to be wetter than the young one (Lowry and Hastings, 1952)—in contrast to the general desiccation of tissues with aging, including loss of ground substance (Gersh, 1959)—and the protein content may be down 25 per cent, with comparable fall in phosphatides and lipids in general (Burger, 1954) A decreased metabolic turnover of various substances has been reported (Mannell and Rossiter, 1952) and also questioned There is no evidence for decreased sensitivity of specific receptors or of speed of response of muscles—although this latter has not been particularly sought The shape of a dark adaptation curve is unchanged with age, but light sensitivity falls (Birren, 1959) This may well be due to central rather than peripheral changes,

especially since hypoxia, which probably affects the retina, alters both adaptation and sensitivity (McFarland and Fisher, 1955; see also below, chaps. xv and xvi).

The above account shows clearly that changes at the cellular level are moot and certainly not dramatic, yet failure of performance at the organ level is unequivocal. Somehow, the interactions of the units, and perhaps a decrease in their number, are far more disturbing than are the changes within the units themselves. Moreover, complex performance clearly deteriorates more than does simple performance at the level of the entire nervous system. Simple auditory reaction time increases from 0.20 second in the young to 0.25 second in the old, but the interval between warning and activating stimulus for maximal effectiveness is 2.5 seconds in the young and 3.5 to 4.0 seconds in the old (Birren, 1955). The startle response takes over twice as long in old as in young people, and the speed of simple copying of digits is cut down to less than one quarter in the oldsters (Birren, 1955). The more intricate the task, and the more the judgment demanded for it, the greater the deficit in the old versus the young, and this is true not only for time required for simple performance but also for avoiding errors.

The information about age changes in psychomotor skills has been reviewed by Welford in chapter xvii; here we are concerned with the implications of such information for the state of the organism. The old person needs continuous reassurance or new information as he proceeds, obtained by repeated visual examination of the stimulus situation and of his own motor performance (Bartlett, 1955). The perceptual and conceptual models of the world seem to diminish, and certainly form less easily with age (Szafran, 1955), so that this steady information reinforcement becomes essential. Moreover, more errors are made in translating spatial perception into motor performance (Kay, 1955*a*, 1955*b*). Input and output tend to be more tightly coupled, and it becomes difficult to change an existing coupling (habit) in the old. Thus an error made once or twice during learning is very hard to eliminate, and a change in set or operating conditions is not easily made (Ruch, 1934; Welford, 1950). There is also greater retroactive inhibition of memory (Birren, 1959). The programming of future actions is markedly interfered with, whether involving a loss of recent memory or not, so that most of the slowing of performance is in the pauses between successive acts rather than in a slowing of the acts themselves. At any age it takes twice as long to "aim" an action as to perform it (Singleton, 1955), and this aiming takes progressively longer with age. A sequence of acts is broken down into a series of individual ones with pauses between—much as a simple co-ordinated movement is dissociated into its components in cases of interference with proprioceptive and cerebellar systems.

In general, the old lose speed and flexibility and lack the kind of reserve and coordination that makes for maximal performance. This is seen at the motor level, since the more complex the athletic performance, the more is practice required to maintain high efficiency, and the better the performer, the more does practice benefit his performance. Similarly for organic brain damage, animals with brain lesions perform simple tests as well as intact rats but perform miserably on the really complex ones (Lashley, 1929). Not only gross anatomical insult but physiological or pharmacological stresses also affect the integrated functions of the nervous system more dramatically than the simpler ones. Behavioral failure follows down the metabolic and functional gradient in the nervous system, so that fatigue, sleeplessness, a great variety of drugs, oxygen or fuel deficit, and the like disrupt functioning from the cortex down, and the more complex performances go out long before the reflex arc is seriously disturbed. In general, what Henry James called "sagacity," or the ability to cope with life, deteriorates with age, perhaps later than do the simpler mental

abilities, because experience and wisdom certainly grow for a time after speed, memory, learning ability, simple reasoning, and the like begin to fail

VII Neurone Interaction

It is possible with current neurophysiological knowledge (e g, Gerard, 1958) to account for most, if not all, of the performance deterioration of the aged in terms of the interactions of the neurones of the brain The deficits in the aged can largely be understood in terms of a decreased number of functionally available neurones and of a prolonged time for the fixation of an experience or a memory Neurones may become functionally unavailable both by anatomical loss and by physiological grooving or irreversible entry into some fixed neuron assembly With such a decreased functional reserve, conceptual categories decrease alternate paths to a solution become fewer and the going ones are more firmly held to, and general reasoning is slower and integrated judgment poorer The well etched patterns of travel through neuron assemblies give the firmer habits and the greater rigidity of performance under familiar circumstances, just as the lack of reserve limits the innovative behavior available to meet new circumstances

The poorer and slower fixation of a new experience is responsible for loss of recent memory, for the need of a multiple sensory input to control movement and the similar intensive visual guidance of performance, for the breakdown of decisions and movements into single series components and the slowing of such sequential processing, and, of course, for the increased difficulty of intellectual model building The behavioral consequences are well summarized by Kay

> For the very reason that an adult has found that certain features of his environment can be adequately responded to in a particular way the more difficult it is for him to react to those situations where such responses are for once inapplicable This is the obverse of the coin of experience We might consider this as follows A complex biological mechanism is capable of adapting itself to meet the probabilities of events—a form of experience—but by very reason of the fact that this makes for ease of maintaining performance it also makes the organism less well equipped when the improbabilities occur [1955a, p 265]

The above suggestions are, of course, hypothetical, but several definitive experiments could easily test out these neural changes with age

A prediction is that summation of impulses at synapses, and the consequent ease of irradiation of activity through neuron nets, would diminish with age This could be tested by introducing stimuli through buried electrodes in chosen brain sites and observing the magnitude and speed of activation (or inhibition) developed at other points in the brain at various distances and through various connections Irradiation should be definitely poorer in the old than in the young brain Perhaps a quick and simple indication on this point could be obtained by examining the magnitude of Traube Herring waves in young and old humans These respiratory effects on blood pressure—even more on heart rate—are partly due to irradiation from the respiratory center to the cardiovascular ones The effects should diminish with age

If as has been reported, the Rasmussen stain can indeed reveal all the synaptic connections on a given neuron, studies of old and young brains with it might even reveal an anatomical component for the expected physiological alterations, but it is hardly likely that all the changed electrical and metabolic factors would appear, even yet, under the microscope—or even the electron microscope

The entire problem of reversibility and irreversibility is well exemplified in the normal functioning of the nervous system When an impulse shoots along a nerve fiber, it leaves behind after potentials which last a few thousandths of a second, metabolic changes which last a few minutes, and ionic redistribution processes that may last hours After a few hundred impulses in

rapid succession, these changes are greatly prolonged after potentials may last minutes metabolic changes hours and pumping for an unknown length of time Synaptic junctions bombarded for a few seconds transmit messages with many fold greater ease and this facilitation can last for hours Conversely synapses left completely inactive for weeks may fail to transmit messages until they have been reactivated by bombardment for some time

Hamsters or rats, allowed to learn a maze in repeated daily trials will still learn perfectly well if given a daily electroconvulsive shock several hours after the trial If the shock follows the trial by only a few minutes however, no learning occurs There is thus a period during which a reversible change in the nervous system induced by incoming impulses becomes an irreversible mnemonic residue It is tempting to attribute this to the reverberation of messages over neuron loops, if a few hundred impulses can prolong the changes left by activity by many orders of magnitude a hundred thousand or more repeating impulses might well leave an essentially permanent engram Experiments are now in progress on the influence of various drugs on the time required for fixation fixation time would be expected also to increase with advancing age—another experiment that could easily be done

VIII Conclusion

This excursion into aging and the organization of behavior makes no pretense at completeness but claims only to highlight certain relationships and to present a viewpoint. Aging and death are of great interest to man but they may be of little importance to nature Other animals may experience fear when the threat of death is imminent but surely only man is self conscious about mortality and immortality For nature the group takes precedence over the individual just as does the individual over its cells or the cell over its molecules Here arise such questions as the relative value of a slow or a rapid turnover of generations whether many short lived ones have an advantage over few long lived ones or vice versa This is perhaps most clearly seen in the plant kingdom as between the annuals, depending entirely on seeds and the perennials depending also on cambium or other surviving somatic cells

Whatever the primitive situation man will certainly continue to tinker with his aging and will undoubtedly progressively increase individual longevity The sociological consequences of an aging population are clearly most important at the behavioral level rather than at that of mere life or even of physical health To maintain life without health is tragic to maintain life and health at the animal level without the capacity for interpersonal human behavior is only less so The dominant challenge of aging at the human level is at the higher reaches of organization where the integrative functioning of the nervous system permits a rich and labile behavior and the social organization of men uses and rewards such behavior

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PART THREE

Aging in Environmental Settings

X

Social-Cultural Background of the Aging Individual

OTTO VON MERING AND FREDERICK L WENIGER

This is a basic information chapter on the social cultural background of aged individuals in contemporary Western society in the light of known cultural and socioeconomic variables This task involves the delineation of some of the significant contributing concomitant and consequent sociocultural factors conditioning the experiences of aging individuals Put differently we will describe some of the ways in which modern man as both the creator and the product of his sociocultural environment sees himself and acts as an old person

To do a discussion of such a broad topic full justice it would be desirable to use a life span or developmental psychological perspective Pressey and Kuhlen (1957 p 654) have followed this approach admirably in their recent work on the psychological and cultural aspects in the growth and decline of the individual It is beyond the scope of this chapter to pursue this orientation in all its ramifications Rather we shall focus on constants and variants in only some major and common problems of preparation for and adaptation to late maturity and we shall discuss these in the light of changes in salient aspects of the

erce and traditional views of the desirable way of aging and their modern counterparts of expert opinion serve as a point of departure The focus then shifts to a re examination of the broad social implications and consequences of the changed age and mortality profile of today The argument proceeds with a discussion of the aged as an emergent minority culture and of their special experiences of social deviation and of medicated survival We continue and conclude with an analysis of changes in the sociopsychological meaning of normal senescence and in the ability to master common and unique life stresses such as work and retirement relations with peers and others illness and accidents disability and death

I PERSPECTIVE

The individual and social problem of aging of what it really means to become old has fascinated and troubled social thinkers from ancient times In order to achieve the proper perspective about the reasoning and opinions of today s experts in the field of gerontology we must be familiar with the medical and philosophical views current in Greek and Roman times

The ancient old age experts were as limited as modern experts in *not* possessing *sure* biological tests and standards to establish just when old age begins or senescence is actually reached The ancient Greeks and Romans did not have reliable birth records to study old age patterns systematically and chronologically in a whole population The best available information and opinions about old age usually

stemmed from the lips and writings of wise aged persons reflecting on their own unique experiences and on the nature of the association of young people and adults with the aged

Today we do possess the ability to use reliable birth records and other vital population statistics and many special physiological psychological, and aptitude tests to establish facts and trends about the aged in society However, we still must revert to social and cultural criteria for determining the onset of old age if we wish to communicate intelligibly with others about its meaning No uniform schema based on chronological age alone is a usable criterion from adult middle age to old age (Pressey and Kuhlen 1957)

A person is "old" or better perhaps, "aging" when he is so regarded and treated by his contemporaries and by the younger generation and when he himself has read the culturally recognized individual and social signs symbolic of membership in the generation of elders The only matter of individual choice open to the old person has to do with whether he wishes to accept or postpone belief in his new identity and act accordingly

While the biological and physiological signs of transience into old age are seldom abrupt the social cultural signs may be so experienced by the individual that they may cause him to attempt rebellion and subterfuge for a time It is only the basic uncertainty as to the place, the time, and the manner of his end that keeps man from distinguishing the destiny toward which he continually advances The uncertainty diminishes as the chances increase for his body to ripen into a fatal infirmity

These social and biological dilemmas of old age were as real to the Greeks and Romans as they are to us today Together with them we still share some of the same basic fears and uncertainties Only some of our attitudes, opinions explanations, and solutions are different but not necessarily more protective and reassuring

II Greek and Roman Views of Aging

Among the Greeks and Romans expert and popular descriptions of old age ranged from the optimistic to the pessimistic extreme Aristotle, like Horace and Juvenal, dwelled on the unfavorable aspects of old age To Horace and Juvenal the realistic recognition of the peculiarities, foibles, and eccentricities of the hoary ones was essential if one wished to live with and understand people Reciprocal negative perceptions of the young and old are epitomized in Euripides play *Alcestis*, in which parents and son and wife berate one another about not wanting to die when the time is "ripe" Aristotle, in the *Rhetoric*, sees very little remaining in old age On the other hand, Plato Cicero, and Seneca see old age in a more favorable light Plato, in the *Republic*, speaks about old age as bringing profound repose and freedom from love and other passions' and as not being in and of itself an intolerable burden

III Contemporary and Historical Descriptions of Aged Persons

We must measure contemporary assessments of the personal and social characteristics of the aged against the Greek and Roman heritage of descriptions Contemporary lists of attitudinal and emotional trait changes reported to occur with age, though not necessarily measured in terms of prevalence are most reminiscent of the foregoing descriptions

A typical description of normal personality characteristics of the aged, based on Rorschach protocols, and reported in 1956, may serve as an example of a large body of existing opinion "*The aged* are characteristically suspicious, anxious, and evasive in their approach to the Rorschach , show a somewhat immature, introversive inner life which is colored by fantasy and unreality , show difficulties in interpersonal

relationships . . . , little awareness of affectional needs . . . , signs of inflexibility, stereotypy, and intellectual impotence" (Light and Amick, 1956, cf Gilbert, 1952) Similarly, a cross sectional study of older men and younger men based on an MMPI item analysis, and reported in 1955, showed the older men in an unfavorable light (Brozek 1955)

The above cited descriptions of the normal personality characteristics of the aged are not dissimilar from those reported on groups of institutionalized older people, except that the latter seem to assume the typical personality of the aged earlier (Davidson and Kruglov, 1952) Other authors also paint a somewhat dismal picture of the personality functioning of the aged, although they also emphasize the fact that mental and physical deterioration may be retarded by encouraging normal community living for older people (Hamilton, 1939, Davison, 1942, Diethelm and Rockwell, 1943, Gardner, 1949)

Since 1952 to the present there has apparently been little change in the general tenor of Rorschach reports on old age (Donahue, 1956) However, an increasing number of experts have begun to question the "willing transposition of the assumed rationale of the Rorschach scoring categories into older age groups" and to call for the standardization of tests like the Rorschach and Wechsler scale for older age levels and peer norms (Caldwell, 1954) Others, like Ames *et al* (1954), concentrate more on the marked individual personality differences among older people and the continuation of 'normal adult responses' among many individuals well past the age of 70 (*ibid*, p 207) Thus, today, ranged along with negative general reports on the personality of the aged, an increasing number of experts on this subject tend to agree that, just as there exists a discrepancy between an individual s physiological and chronological age, his psychological age is not necessarily the same as his chronological age

PERSONALITY AND CHARACTER

We now shift our focus to a comparison of expert early and recent dynamic interpretations of individual differences in the aging experience, a subject that is more extensively covered in chapters xxiii and xxiv of this handbook The role of an individual's character structure and psychological disposition, as conditioned by experience in the production of a difficult or troublesome old age received considerable attention in the writings of Plato and Cicero

Plato in the *Republic,* comments that complaints about the so-called, inevitable discomforts of old age, "as well as troubles with relatives, may well be referred to one cause, and that is not the age . . . but the character of men If they possess well regulated minds and easy tempers, old age itself is no intolerable burden, if they are differently constituted, why in that case, they find even youth is as irksome to them as old age' Cicero says in *De senectute* 'It is not by miracles, speed or physical dexterity that great things are achieved . . . , I am praising that old age which has its foundations well laid in youth . . . If old men are morose, troubled, fretful and hard to please . . . , these are faults of character not of age" (Zeman, 1944–45)

A contemporary expert on the aging experience reveals a remarkable identity of outlook with the ancients when she refers to the following as a major assumption of the "modern concept of aging" (Donahue, 1956) According to her, 'if the older individual is to be a creative active personality in his old age, he must maintain an effective personal relationship with his environment and must adapt to the danger within himself" The timeless theory that an old man becomes what he has been is expressed in a variety of ways by today's experts Psychiatrists like Braceland (1956), Ebaugh (1956), and Busse *et al* (1955) regularly stress that adequate adjustment of the elderly is largely determined by strengths and weaknesses much earlier in life

Some authors, like Raines (1956), make much of the connection between the way an individual handles problems in adolescence and old age and of the predictive value of adolescent response patterns in particular Analysts like Grotjahn (1940) go beyond this view by emphasizing that, as a result of the changed reality situation in old age, where biological and social dependence, or genital impotence and a general feeling of helplessness face the individual, the problems of autonomy and mastery of infantile dependency recur and create severe and often debilitating psychic stress

"ADVICE" TO THE AGING INDIVIDUAL

Greek and Roman expert views of the desirable ways of handling the inevitable aging experience are clearly derived from the extant positive and negative descriptions and interpretations of aging In the *Odyssey* Ulysses has some practical advice for his father, Laertes "Warm baths good food, soft sleep, generous wine, these are the rights of age, and should be thine" The emphasis on maintaining a sufficiently high physical level of comfort through the proper amount of rest, warmth and diet was generally accepted as sound advice in Greek and Roman times The second-century physician Galen advised that in old age, when the body is "cold and dry, nothing contributes so much to a good digestion as a sound, healthy human body touching the stomach"

Admonitions and recommendations of how to handle one's self as an old person in relation to society as a whole stressed the need of old people to recognize their biological, physical, and memory limitations Older people were also advised to derive courage and understanding, and to plan for different action, by knowingly accepting the inevitable frailty and decay of the body

This classical heritage of practical advice for preparing for a happy old age exists in most contemporary scientific writings However, biblical, especially Old Testament, references to the personal and social management of problems of aging have to this day remained the most important background of all religious, governmental, and lay thinking about the later years of life (Zeman, 1944–45) A handbook on *The Older Person in the Home* states optimistically

> The possibilities are great today for older people to enjoy busy and useful lives They can continue to play an active and constructive role in the life of their families and community We need their judgment their experience, their stability
>
> It is within the circle of the family that these traits can be realized most effectively and most completely For the older person a full and integrated family life can spell the difference between loneliness and fulfillment—between frustration and independence It's up to you to make the three generation family flourish and succeed [U S Department of Health, Education, and Welfare 1957c, p 29]

Similar exhortations to the aged and admonitions regarding the duties of children in relation to the aged are commonly found in Ecclesiasticus (Wisdom), Leviticus, Exodus, Proverbs, and other books of the Old Testament Specific wise advice about the essentials of achieving a sound later maturity, such as an adequate but limited food supply, the control of exhaustion, the development of high motivation and special recreational activities and hobbies, and the need for privacy without isolation abound in today s literature, but they are in themselves not different from what we can gather from reading the ancient literature (National Social Welfare Assembly, 1946, Stieglitz, 1946, Grotjahn, 1951, Clarke, 1952, Keys, 1952, Stern and Ross, 1952, Nisbet, 1953, p 184, Rusk and Taylor, 1953, Goldfarb and Sheps, 1954; Ogg, 1954, Goldfarb, 1956)

What is different today is that the paths of reasoning which lead to today's experts' conclusions are unlike those of the past and that many of the special "aspects of biological experience, growth, maturation, and aging are now capable of reasonably accu-

rate measurement (Bortz 1957) Finally and perhaps most important is the fact that the entire socioeconomic and cultural context of living and functioning as an aged person has changed This has made for significant differences and modifications in the particular avenues or solutions whether institutionalized or individual that are open for the achievement of a happy and creative later life

The foregoing survey of the classical and biblical heritage and of contemporary assessments of the problems of aging and old age clearly indicate that the broad field of gerontology is still very much in its infancy When as has been shown very few things heard and written today in fact represent new or original insights there is a constant danger that such a field become susceptible to a profusion and even confusion of points of view Practical considerations of dealing effectively with immediate problems often becloud the more vital problem of building better or more systematic conceptualizations However much new and expert theory building is needed if we wish to explain in a more organized fashion the existence of a large number of apparently unrelated phenomena which are a part of the process of becoming old

The serious investigator should conduct his experiments and arrive at conclusions always in the light of a thorough awareness of the major socioeconomic facts and conditioning forces which shape the experiences of the aged today This is perhaps the chief reason for writing a basic information chapter and for beginning the main body of our discussion with a careful re examination of some of the important social and economic implications and consequences of the changed age and mortality profile of today

IV Length of Life

The extraordinary extension of the average life in the Western world dur ng the last one hundred years is a unique phenomenon with far reaching effects on the fabric of society This chapter is concerned with the social consequences of length of life chapter xi is concerned with influences upon length of life Today longevity has reached 70 years (Metropolitan Life Co 1956) Our ancestors who lived in early Iron and Bronze Age Greece had a life expectation at birth of only 20–30 years the Mongols were middle aged at 30 and very old at 40 but people in the United States can look forward to an average length of life of 70 years today (Health Information Foundation 1956) (see Fig 1)

The rise in Western life chances during the past century has been greater than that of the previous two thousand years and it has been concentrated in the period since 1890 International differences in life expectancy within the Western world have declined and more significantly certain past trends in Western mortality patterns are unrepeatable Future developments in this will have to come in the ages beyond 60 (Stolnitz 1955) These and other facts about increased life expectancy will be raised again later in this section

Proportion of Aged in Society

The significant increase in the proportion of the aged in the total population is directly associated with the increase in life expectancy (Table 1) The magnitude of the population shift in the direction of older age groups becomes apparent when we consider the fact that since 1900 the population of the United States has almost doubled but that the number of persons 65 years and older has more than quadrupled In 1900 the percentage and number of persons 65 years and over in the total population amounted to 4 1 per cent or 3 080 000 individuals By 1950 the proportion of aged in the population and their number had risen to 8 2 per cent or 12 300 000 individuals representing a net change of 4 1 per cent (Fig 2) Today the proportion and number of aged stands at 8 6 per cent or 14 400 000 of the total population This continuous increase since 1900 may be bet

ter appreciated if we consider that today a thousand persons reach age 65 each day

By 1975 it is predicted we can expect one in ten of our total population in the upper age bracket with about 138 older women for every 100 older men (U S Senate Committee on Labor and Public Welfare 1957) The estimate for the percentage and number of persons 65 and over in the total population in 1975 is 9 4 or 20 600 000 This continuous increase in the proportion of people over 65 years in the

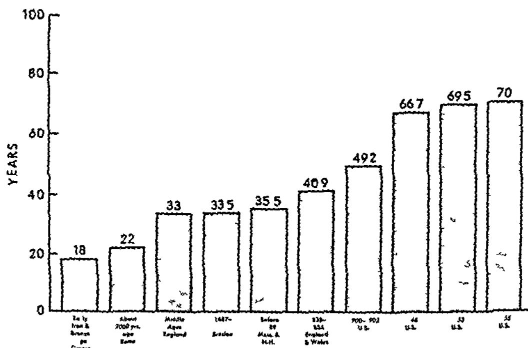


FIG 1 —Average length of life from anc ent Greece to modern times (Adapted from Dubl n *et al* 1949 p 42 1953 data from U S Office V tal Statistics 1955 data from Metropolitan Life Co 1956)

TABLE 1*

NUMBER AND PROPORTION OF THE POPULATION 65 YEARS OF AGE AND OVER UNITED STATES 1880–1956 AND ESTIMATES TO 1975†

Year	No of Aged	Per Cent of Aged to To al
1900	3 080 498	4 1
1930	6 633 805	5 4
1940	9 019 314	6 9
1950	12 322 000	8 2
1956	14 404 000	8 6
1960	15 800 000	8 8
1975	20 655 000	9 4

* Source U S. Bu eau of the Census (1953 Tab e 39 pp 1 93 U S Bu eau of he Census (95) p 11 and U S Bu eau of the Census (1955a) p 8

† Es ima es for he total population based on the assumption of most apid popu a on growth that is the 1954 55 level of population grow h will ontinue to 1975

total population is reflected in the fact that between 1850 and 1950 the median age of the total United States population has risen from 18 9 to 30 1 years (Table 2)

There were increases in all age groups over 35 years since 1950 but the percentage growth in the general population almost consistently decreased from decade to decade while that of the aged (65 years and over) has been increasing since 1920 (Table 3) In fact at no time since 1870 has the rate of growth in the population aged 65 years and over been as low as that of the United States population as a whole In other words the aged segment of the population is growing more rapidly than the general population

LIFE EXPECTANCY BY COLOR AND SEX

We shall now consider some further aspects of the continued increase in United States life-expectancy we mentioned earlier While the increase in life-expectancy has been general for the whole United States population, there exist significant differences between the sexes and white and non white populations White and non white women live longer than males, and their percentage representation in the population increases with age

During the period 1909–11 the life-expectancy for white males under age 1 was 50 2 years, by 1952 it had risen to 66 6 years During the same period the corresponding average future lifetime for white

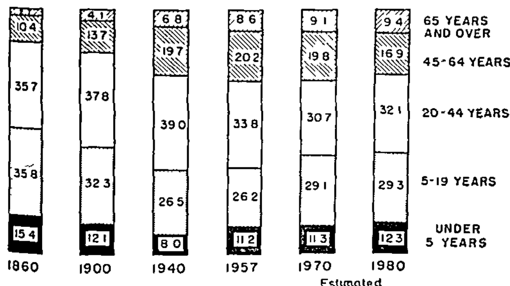


FIG 2 —Population structure of the United States by percentage of the population in selected age groups Data for 1860, 1900, and 1940 are from Dublin *et al* (1949), data for 1957, 1970 and 1980 are from U S Bureau of the Census, *Current Population Reports* November 10 1958, Series P 25, No 187, Table 1

TABLE 2*

POPULATION OF THE UNITED STATES, BY AGE, 1950 AND 1850

AGE	No		PER CENT	
	1950	1850†	1950	1850
Under 10	29,565 000	6 743 185	19 6	29 1
10–19	22 094 000	5 423 744	14 7	23 4
20–29	23 420 000	4 279,958	15 5	18 5
30–39	22,794 000	2,827,577	15 1	12 2
40–49	19,048,000	1,847 806	12 6	8 0
50–59	15,504,000	1,110,226	10 3	4 8
60–69	11 010,000	610,301	7 3	2 6
70 and over	7,262 000	349 079	4 8	1 5
Total	150,697,000	23,191,876	100 0	100 0

* Source Tibbitts and Sheldon (1952) p 3

† Figures include adjustments for age not reported.

females increased from 53 6 to 72 7 years (Fig 3)

The average future lifetime for non whites while following the same trends, is considerably less That is to say non white males do not live as long as white males, their life-expectancy at under 1 year in 1952 was 7 5 years less than for white males For non white females the life ex pectancy was 9 0 years less than for white females in 1952 (Fig 4)

Both the extension of the life span and the sex and white–non white differentials

TABLE 3*

RATES OF GROWTH FOR THE GENERAL POPULATION AND THE AGED POPULATION BY DECADES UNITED STATES 1870–80 TO 1950–56

Decade	Per Cent Growth of Total Population	Per Cent Growth of Aged Population
1870–80	30 1	49 4
1880–90	24 9	40 5
1890–1900	21 4	27 1
1900–1910	21 0	28 2
1910–20	14 9	24 9
1920–30	16 1	34 5
1930–40	7 2	36 0
1940–50	14 5	36 6
1950–56	7 0	16 9

*Source Drake 1958) p 48 U S Bureau of the Census (1953) Table 39 pp 1 93 and U S Bureau of the Census (195 b) p 11

are directly related to significant changes and differentials in the mortality rate The sex differential has *markedly* influenced the total United States population structure In the early part of this century men out numbered women in this country in almost all age groups This is attributable mainly to the heavy immigration at that time and to the fact that the majority of the immi grants were males It was due also to the normal 5–6 per cent annual excess of male births

With the decline of the immigration rate, however, and a continual increase in the annual excess of male deaths, the male population soon became a minority, and today women outnumber men at all ages past the mid twenties The excess of women has become especially great among people aged 65 years and over In 1956 this excess amounted to over a million, and it is increasing steadily It is estimated that, if present trends continue, this excess will rise to 3 25 million in 1975, that is, the ratio will be 100 men to 138 women A similar excess will hold also at mid life (ages 45–64), there will be 2 2 million, or 11 per cent more women than men in that age category (Health Information Foundation, 1957e, p 5) (see Fig 5)

It is interesting to note that excess male mortality is not unique to the United States but is common, with only minor exceptions, throughout the world As a rule, the reported differences in male and female mortality rates are greatest where life-expectancy for both sexes is highest, they widen as mortality rates decline in each country (United Nations, 1955)

Regardless of sex differences in mortality rates, the over all decline in death rates for all ages of the American population has been an impressive 46 per cent since the turn of the century (Health Information Foundation 1956, p 1) The reductions in death rates have different meanings for various age groups and for the white and non white population Not all age categories have been equally affected by mortality declines, and any increase in life-expectancy is related to declines in the mortality risks to which man is subjected throughout his life-span

INFLUENCE OF CHANGING INFANT MORTALITY

The increase in life expectancy is largely a result of successes in combating infant mortality due to childhood diseases like diphtheria and scarlet fever and tuberculosis and is a result of a reduction of mortality risks due to communicable diseases like influenza (Health Information Foundation 1957b)

Of all children born around 1900, less than 60 per cent would have reached 50 years of age, but by 1948 this percentage had increased to 86 per cent (Tibbitts and Sheldon, 1952) Stated differently, about 11 per cent of the white babies born in 1900 would not survive their first year of life, and, of Negro babies born in 1900, nearly 23 per cent died in their first year of life An even greater difference is seen at the age of 5 years About 18 per cent of white and 34 per cent of Negro babies born

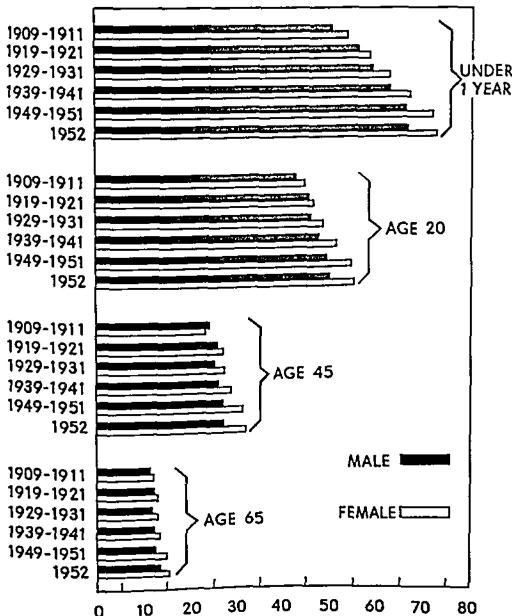


FIG 3 —Average future lifetime in years for whites at age indicated, United States, 1909-52 (After Clinard 1957 p 417)

in 1900 would have died by the time they reached school age, their fifth birthdays, as compared with 3 and 5 per cent respectively, in 1953 (Health Information Foundation, 1956)

Clearly, the rate of decline in mortality has been more dramatic among the Negro than the white population. However, there has been a consistent downward trend in mortality in the whole United States population, and thus larger proportions of the population now survive to more advanced

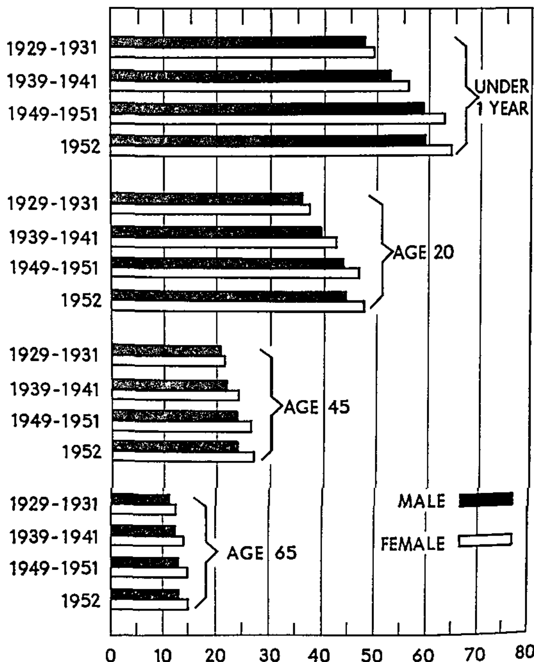


FIG 4—Average future lifetime in years for non whites at age indicated, United States, 1929–52 (After Clinard, 1957, p 418)

ages On the other hand, since 1850 and until recently, little or no progress has been made in increasing the average life expectancy by reducing the death rate from certain diseases of old age, that is, improving the life-expectancy of persons who have reached 60 or 70 years (Shock, 1957) For example, the average life expectancy of white males, aged 45 years and over, increased only from 23 9 years in 1909–11 to 27 1 years in 1952 (Fig 3)

Since 1940, however, and with the spectacular development of antibiotics, the chances of surviving at older ages are increasing, though only slowly We can understand this better if we examine briefly the differences in mortality rates and trends in the period 1890–1949 We know that the increase in the survival rate during this time was most significant in the younger age groups, though through 1890–1949 a constant high survival rate was evident for people of all ages but especially for women Since 1940, mortality showed a significant decrease in the older age groups except for men aged 50–65, the "coronary age" (Lewis, 1953)

The foregoing makes it clear that the preceding century and especially the past 50–60 years have witnessed a significant demographic movement Although it is not a shift of a given large population from one part of the world to another it is a 'migration across the boundaries of age that has a comparable impact on the entire sociocultural fabric

The change in the age composition of the population not only is a result of declining death rates but is due also to a general decline in birth rates throughout western Europe and in the United States for the past century Whether this is a reflection of the spread of knowledge about contraception or an expression of significant sociological and economic changes in the lives of married people is not important for the moment It appears to be a result of a combination of these factors

In the United States since 1850, there has been a distinct decline in the ratio of children under 5 to women of childbearing age, though at present this trend seems to have slowed down In 1850 the adjusted figures for the United States white population were 892 children under 5 years per 1800 women aged 20–44 years, in 1940, the figures show only 419 children, or less than one half of the 1850 figure (Whelpton 1947 p 16)

The striking shift in the proportion of the population under 5 years to the aged segment of 65 years and over adds another meaningful perspective to the increased life expectancy of our day Indeed, some loss or decrease in the proportional repre



Fig 5 —Sex ratio of persons aged 65 and over United States 1900–1955 and projections for 1965 and 1975 (From Health Information Foundation 1957e p 5)

sentation of all ages under 30 is detectable for the United States population as a whole as compared with a gain for all ages of 45 years and over Table 4 illustrates the percentage loss for age level under 5 years and the corresponding percentage gain for level over 65 years

To repeat, the reason for this phenomenon is the increase in the absolute numbers of the aged population, it is due to the simultaneous decreases in mortality and birth rates One of the important social implications of an increase in both the size and the number of aged is that there will be fewer adults in their productive and active years to take care of an essentially non productive population that is either too old or too young for full or working participation in society The extension of life expectancy and rigid retirement policies have

had the combined effect of increasing the number of persons in retirement so that the aged must live longer as non productive dependents (Drake, 1958, p 431)

PROPORTION OF PRODUCERS AND NON PRODUCERS IN POPULATION

Broadly speaking the ratio of producers to non producers may indeed be decreased for a while by artificially postponing the time of entrance of the young into the labor force, as, for example, by sending the

TABLE 4*

PERCENTAGE OF POPULATION 65 AND OVER AND UNDER 5 YEARS OF AGE UNITED STATES 1880-1956

Year	Per Cent of Total	
	65 and Over	Under 5
1880	3 4	13 8
1890	3 9	12 2
1900	4 1	12 1
1910	4 3	11 6
1920	4 7	10 9
1930	5 4	9 3
1940	6 8	8 0
1950	8 2	10 8
1956	8 8	11 4

* Source Drake (1958) 1 0 U S Bureau of the Census 1953) Table 39 pp 1-93 and U S Bureau of the Census 1957b) p 11

family offspring to college Or it may be further decreased by the setting up and strict enforcement of retirement regulations (Drake, 1958, p 431) Both events are characteristic patterns in today s socioeconomic life and are not likely to change until more flexible and adaptive higher education and retirement policies are instituted

Before we discuss some of the particular demographic and social characteristics of the bulge in the older age population as aspects of present-day industrial society, it is well to examine briefly the question of whether the mean life span as well as the maximum life span has changed due to socioenvironmental factors Mortality statistics, cross-sectional and longitudinal, are limited in the information they can provide about "inherent" rates of aging in man The "real," inherent, or metabolic aging curve cannot be isolated from changes of extrinsic or environmental origin Thus we cannot attribute biologic significance to the shape of today's mortality curves

DISTRIBUTION OF MORTALITY BY AGE

According to Davies (1954), there is no evidence that, when we compare the mortality distribution curves for ancient Rome

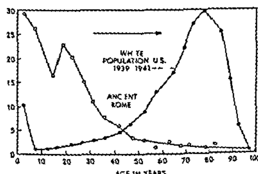


FIG 6 —Mortality distribution curves for ancient Rome and the United States 1940 (After Davies 1954 p 191)

and the United States in 1940, a change in maximum life span has occurred The mean life span in Roman times has been estimated at between 18 and 22 years (Fig 6) Endemic and epidemic infections accounted for a large portion of the mortality The two mortality curves in Figure 6 show that the underlying aging process has not changed but only that improved health measures have altered life expectancy

The two curves have three characteristics in common They show a decreasing mortality rate during the first decade of life, a minimum mortality rate during the second decade, and, finally, a maximum life span of approximately 100 years When seen in this light, it is perhaps possible to say that the mortality curves during the first and

second decades of life appear to be "inherent" as they have not been substantially altered by the known and pronounced environmental "health" changes in our day

The marked shift to the right of the mean and mode of the mortality curve is chiefly a result of better control of diseases of extrinsic origin Death has never alone been due to the wear and tear of the environment In other words, the maximum life span has been shown to be dependent on the environment. Thus it is safe to say that future developments in the improvement of environmental factors will have to alter life-expectancy beyond the ages of 70 or 80, if the 2000 year "barrier" of the maximum life span of about 100 years is to be broken

Let us turn from this sobering picture to consider the rapid increase in the proportion of the aged in the population as a phenomenon associated with the urban industrial development of Western civilization in the last 100 years The changes in the composition of the population brought about by a decline in birth rates and a reduction of infant mortality and a greater life expectancy for all up to the age of 45 are in fact inseparable from the urbanization and industrialization of Western society Industrialization not only brought with it an increased emphasis on the values of health and longevity and the introduction and spreading of mass public health programs and research The application of industrial techniques to food production and processing that increased the total amount of safely consumable food supplies is equally significant

Industrialization.—This fact can be demonstrated in two ways Extant demographic data show there exists a significant disparity in the proportion of old people between industrially advanced and industrially underdeveloped countries According to Moore (1950), the population aged 65 years and over in India and Burma in 1931 represented only 2 2 per cent of the total population In 1940 the aged (65 years and over) in Brazil accounted for 2 4 per cent of the total population, in Colombia, for 2 9 per cent in Chile, for 3 5 per cent, and in Mexico for 3 0 per cent By comparison, the proportion of the aged 65 years and over in the United States in 1940 amounted to 6 8 per cent

Another way of illustrating the role of industrialization in the increase in the aged population is to compare the proportion of the population aged 65 years and over through a period of time during which different countries have become more industrialized For example, from 1890 to 1940, a period of rapid industrialization, the United States showed an increase of aged from 3 9 to 6 8 per cent of the total population (Table 5)

TABLE 5*

PROPORTION OF THE POPULATION AGED 65 AND OVER† IN SELECTED COUNTRIES AT VARIOUS CENSUS DATES 1880–1901 AND 1930–47

Country	Date	Per Cent	Date	Per Cent
Australia	1901	4 0	1947	8 0
Austria	1880	4 4	1934	7 9
Belgium	1900	6 1	1930	7 6
France	1891	8 3	1936	9 8
Switzerland	1900	5 8	1941	8 6
United States	1890	3 9	1940	6 8

* Source Moore (1950) p 27

† Based on official national statistical sources

Urban rural change.—Changes in the rural urban distribution of the aged in the past generation also seem to reflect the increasing urbanization and industrialization of society Since around 1920, when rural areas still contained a disproportionately large amount of aged people, the aged have become increasingly concentrated in urban areas (Smith, 1955) with extremely favorable climatic conditions, as in Florida and Arizona and on the Gulf Coast and the Pacific Coast.

In the years following World War I, a heavy overconcentration of older people existed in villages and small towns in the United States However, since 1920, the city has become the preferred place of resi-

dence for older people so that, by 1950, urban districts exceeded their proportionate share of the aged when compared with rural non farm areas (Smith 1955) This is related to the emergence of a truly urban society in the United States during this period with the vast majority of people being born and reared in the city Despite this shifting of the aged population from rural non farm to urban areas however United States farms and rural centers of less than 2500 population have to this day remained the 'home of old folks That is during the past few decades, the proportion of older people on farms has decreased only slightly in relative importance

The foregoing makes it clear that the number and degree of felt problems about our aged population would vary according to their overconcentration in certain geographical regions In this connection it is necessary to discuss the role of migration among the aged population It is generally agreed that the migrations of the aged and the young which took place in earlier decades will influence the regional distribution of the aged population

Mobility—According to a report, people in their twenties are the most mobile of all age categories (U S Bureau of the Census, 1956) For example, approximately 37 per cent of these persons changed their residence during a 1 year period (March, 1955—March, 1956) Among people 30 years of age and over, mobility gradually decreases as their age increases, but among retired people (65 years and over) only 10 per cent changed their residence during the same year (Table 6)

In general, the data reveal the aged population to be relatively stationary, preferring to remain in their own homes and communities in later life If they move it appears that most prefer to change their place of residence within their county only or from county to county within their home state Even though older women appear to be more geographically mobile than men around 90 per cent of all mobile old people moved around within the same state only

It is true that outmigrations of young people to more promising economic areas in the western United States from given areas in the North, East and South will change the age composition of the areas they leave But it is equally true that these migrations will have an impact on the areas into which they move, for, as these young people move into higher age categories they may be joined by some of their aged relatives especially by their widowed mothers

On the whole, the history of the ecology of our aging population reveals that the present distribution of the aged in the United States is more related to the prior distribution of people in the younger age categories (Smith, 1951, Vance 1954

TABLE 6*

MIGRATION OF THE AGED POPULATION BY NUMBER, PERCENTAGE AND SEX UNITED STATES 1955–56

Type of Move	Total Aged		Males		Females	
	No	Per Cent	No	Per Cent	No	Per Cent
Non movers	12 961 000	99 0	6 020 000	90 3	6 941 000	89 7
Movers	1 441 000	10 0	650 000	9 7	791 000	10 3
Same county	1 039 000	7 2	458 000	6 9	581,000	7 5
Different county	402 000	2 8	192 000	2 9	210 000	2 7
Within state	225 000	1 8	127 000	1 9	128 000	1 7
Between states	147 000	1 0	65 000	1 0	82 000	1 1

* Source D ake 1958) p 37 U S Bureau of the Census (1957B) p 11

Hitt, 1956) That is to say, while older people do migrate, the majority remain concentrated in the same states and regions decade after decade For example the growing number of aged in northeastern United States is related to the many young people who migrated to this area during the earlier years of the industrial expansion and who chose to remain in their old age

A thorough current appraisal of the com position of the aged population itself must go beyond the description of rural urban differences and of migratory and sedentary characteristics Older people differ signif icantly not only from the total population in color and sex but also in nativity We will recall that non whites are relatively un derrepresented among the aged because of the life expectancy differential While non whites constituted over 10 per cent of the total United States population in 1950 they represented only 7 per cent of persons 65 years of age and over (Price and Hitt 1955)

SEX IMBALANCE IN AGED

With regard to the imbalance between the sexes we found that aged women out number aged men in the United States In 1950 there were 100 aged females for every 90 males aged 65 years and over (U S Committee on Aging and Geriatrics 1953) This is a reversal of the ratios for the years 1900–1930 which existed in part because of the numerical dominance of immigrant males entering the United States prior to World War I The present day imbalance in the proportional underrepresentation of aged males and non white population as compared with older women in the total population was found to be largely due to a higher death rate among males and the non white population This allows relative ly fewer to reach an advanced age A more rap d decline of mortality among females is an equally important contributing fac tor

Nativity —While the aged male and non white populations are on the whole under represented among the aged the foreign born are relatively more numerous among the aged than among the total United States population In 1940 while one of every five older persons was foreign born, only one of every ten persons was foreign born in the total population This differen tial is clearly related to the virtual end of large scale immigration after World War I and to the decline in the productive and economic importance of the foreign born in the United States population (Hitt 1956)

Marital status —We continue our ap praisal of selected demographic character istics of the aged population with an exam ination of the distribution of marital status between aged males and females Bureau of Census figures indicate that the percentage of aged men and women who have never married as well as the percentage of each sex who are divorced are approximately equal However there is a marked differ ence in the percentage of those who are cur rently married and of those currently wid owed (Table 7)

As a rule the aged woman is a widow, while the aged man is married (U S Com mittee on Aging and Geriatrics 1953, p 12) More than two-thirds of aged males (65 years and over) have a living spouse and less than one fourth are widowed On the other hand only 36 2 per cent of the aged females are married and more than half are widowed Both the fact that mor tality at all ages is lower for females and that wives are generally younger than their husbands contribute to this differential This situation tends to be accentuated be cause of the prevalent social custom of widowers and older men to marry younger women while most women refrain from marriage to younger men and many more widows than widowers do not remarry

Living arrangements —The living ar rangements of the older age population are of course closely related to the above mari tal status patterns although they do not follow these patterns exactly According to 1950 data nearly 70 per cent of the aged in the United States resided in homes of their own with either a spouse or a close

relative However, this was true for a much higher proportion of men than women (Council of State Governments, 1955, p 11) Less than one quarter of the aged were not living within a family context, which includes approximately 14 per cent who resided alone in their houses 6 per cent who lived in boarding houses, hotels, and institutions and 4 per cent rooming with non relatives (U S Committee on Aging and Geriatrics 1955 p 14) We will discuss the social significance of the marital status differential and pattern of living arrangements in old age later

The extension of the life-span of men and women beyond the marriage of the last child and the preceding facts are reflected in changes in the composition of the contemporary family unit during its life cycle Broadly speaking the change in the past century from an underdeveloped rural society to an advanced urban and industrial culture where occupational and spatial mobility is both easy and common has been accompanied by changes in the size of the family Today the extended family unit, which, as a rule, included more than two children and a number of participating relatives, has been replaced by the smaller atomistic family with fewer children and only occasionally participating relatives as the most common functioning unit (Locke 1940, Bossard and Sanger, 1956)

CHANGE IN FAMILY

Table 8 provides us with a comprehensive picture of selected major events in the life of the small family in the United States in 1890, 1940, and 1950 The age at which men and women establish their families has been reduced, and by 1950 there was not much difference between the age of mates when compared with the age differential prevailing in 1890 Further, the interval between age at marriage and at birth of the last child has been narrowed by 3 9 years This is related to the fact that in 1950 the average number of children for a woman was 2 35 and that her average age at the birth of the last child was 26 years By comparison the figures for 1890 were 5 4 children and 32 years, respectively

In view of the above, we can see that the average 1890 wife who married both later and bore more children was 5 8 years older at the birth of her last child than her granddaughter was in 1950 Similarly, the average 1950 father was 7 2 years younger at the birth of his last child than his grand father was in 1890

To continue the interpretation of these figures we see that contemporary parents have gained "spare time' beyond the point when their household is still intact with under age children They have gained it not only because of the increase in the average

TABLE 7*

MARITAL STATUS OF THE AGED BY SEX UNITED STATES 1956

Marital Status	Males		Females	
	No	Per Cent	No	Per Cent
Single	468 000	7 0	602 000	7 7
Married	4 616 000	69 2	2 798 000	36 2
Widowed	1 500 000	22 5	4 259 000	55 1
Divorced	86 000	1 3	75 000	1 0
Total	6 670 000	100 0	7 734 000	100 0

* Source U S Bureau of the Census (1956b) p 9

number of remaining years but also because they marry younger and have fewer chil dren and because their children marry younger The 1950 father was 9 1 years, and the 1950 mother 7 7 years younger at the marriage of their last child than their counterparts were in 1890

The extension of length of life together for married couples between 1890 and 1950 is also notable The average married couple of 1890 could expect only 31 years of married life together, and they could not look forward to any time spent alone without children Their marriage would have been terminated by the death of one or the other on the average of 2 years before the mar riage of the last child On the other hand,

as of meaningful work have assumed major proportions in the life of older people to day

Another way of viewing the above changes in the composition of the family during its life cycle relates to the chances of a child becoming an orphan While to day s child under 18 years has about twice the chance of losing his father instead of his mother, only 2 per cent of the orphans in the United States have lost both parents However, there are fewer chances today for a child under 18 years of becoming an orphan than ever before As recently as 1920, 16 per cent of children had lost one or both of their parents due to death With the changes in marital patterns at a younger age and in the number of children per fam ily unit and the marked gains in saving lives in the middle and even older ages, this figure has been reduced to 5 per cent (Health Information Foundation, 1956)

TABLE 8*

MEDIAN AGE OF HUSBAND AND WIFE AT SELECTED STAGES OF THE LIFE CYCLE IN THE FAMILY UNITED STATES 1890 1940 AND 1950

Stage of the Family Cycle	Median Age of Husband			Median Age of Wife		
	1890	1940	1950	1890	1940	1950
First marriage	26 1	24 3	22 8	22 0	21 6	20 1
Birth of last child	36 0	29 9	28 8	31 9	27 2	26 1
Marriage of last child	59 4	52 8	50 3	55 3	50 1	47 6
Death of husband or wife (joint survival from marriage to speci fied age)	57 4	63 6	64 1	53 3	60 9	61 4
Death of husband if last	66 4	69 7	71 6			
Death of wife if last (separate survival from marriage to speci fied age)				67 7	73 5	77 2

* Source Glick (1947 1955)

LABOR FORCE PARTICIPATION

Changes in the participation of the older worker in the labor force and the problems of staying in and entering jobs at an older age are closely related to facts already pre sented In this discussion it is to be noted, however, that people over age 45 and age 65 meet approximately the same kinds of problems

With the shift from a predominantly agrarian to industrial economy, self em ployment has declined and has resulted in increasing the problem of finding a paying job as people become older This has been accompanied by the social invention of retirement which has come to replace the normally expected and comparatively early

natural death of a century ago and has further reduced the opportunity to find employment beyond retirement In addition, a general 'actuarial attitude" to aging, an acquired ability that determines age in years rather than on the basis of function, has put roadblocks into the actual use of an increase in work life expectancy The traditional or Shakespearean concept of the human life cycle as expressed in *As You Like It*, which ends "naturally" with man's second childhood, continues to be applied in the thinking about the aging worker (Linden and Courtney, 1953) It seems as though it does not matter that since Shakespeare s time man's average length of life has more than doubled

The extension of the life span together with the decline in fertility, both also acquired abilities, have increased the absolute numbers of the aged as well as their increased proportion in the total population At the same time, and not unlike the actuarial attitude about aging, the cult of youthful employability has contributed materially to the problems the aged worker faces today in the United States

It may be possible that men have benefited from reduced mortality as shown by an increase in the average length of work-life expectancy Boldly stated, the facts say that males born in 1900 had an average work life expectancy of 32 years In 1956 this figure had risen to 42 years (Health Information Foundation, 1956) The big question remains of how well man can use this increase in work life in the society today

While it is true that length of work life has increased, the number of persons who enter the labor force at 18 years of age has also increased Without question, this has had a "displacing effect" on the use of the older worker, thus quantitatively reducing the benefits of a prolonged work-life expectancy Of white persons born in 1900, 79 per cent lived to enter the labor force at 18 years of age Today, 97 per cent of the whites live to 18 years Of the Negroes born in 1900, only 59 per cent were expected to survive to 18 years, but today 94 per cent live to this age

TABLE 9*

PERCENTAGE OF PERSONS 45 YEARS OF AGE AND OVER IN THE LABOR FORCE BY SEX AND AGE, 1890–1950

Sex and Age	1890	1900	1920	1930	1940	1945	1950
Men							
45–54	93 9	92 8	93 5	93 8	92 7	95 4	94 6
55–64	89 0	86 1	86 3	86 5	84 6	89 9	85 1
65 and over	68 2	63 2	55 6	54 0	42 2	48 8	45 0
Women							
45 54	12 5	14 2	17 9	19 7	22 4	33 3	36 9
55–64	11 5	12 6	14 3	15 3	16 6	24 3	27 3
65 and over	7 6	8 3	7 3	7 3	6 0	7 9	9 5

* Source U S Committee on Aging and Geriatrics (1952) p 54 Data for 1890–45 from J D Durand *The Labor Force in the United States 1890 1960* or 1950 from U S Bureau of the Census *Current Population Reports Labor Force* and unpublished data

Census data indicate that the relative number of aged workers has been shrinking consistently since 1890 (Table 9) The percentage of workingmen 65 years of age and over has dropped from 68 2 in 1890 to 42 2 in 1940 During the tight World War II labor market it rose slightly, only to return to about the 1940 level in 1950

In 1950 the labor status of the older person differed distinctly from that of all persons 14 years of age and over (Hauser, 1954) Of 100 males aged 65 and over, 45 were participating in the labor force On the other hand, for all males, 82 out of each

100 were in the labor force Moreover, nearly one fourth of all males not in the labor force were reported as "unable to work," but over half of the older males in the labor force were reported as unemployable or unable to find work Of each 100 females who were 14 years and older 32 worked in 1950, but only 10 of each 100 aged 65 years and over, were employed All the women in each age category who were not in the labor force were classifid as homemakers But this held true for more aged than younger women Indeed six times as many older women (19 8 per cent) than all women (3 2 per cent) were unable to work

These differences in the labor force status of people 65 years and over have been in the process of becoming accentuated for the last 50 years On the other hand, rates of labor force participation for men 45–64 years of age have changed little (Council of State Governments, 1955) The percentage of men aged 65 years and over who were part of the labor force diminished from 63 2 to 45 0 in the period 1900–1950 When we compare this decline in labor force participation with the increase in survival up to and beyond retirement, we realize the magnitude of the employability problem the aged face today

The following facts give us a graphic picture (Health Information Foundation 1956 p 6) Because of mortality existing in 1900, only 42 per cent of the white babies born would survive up to the compulsory retirement age of 65 years Today 71 per cent will reach this age Among Negroes who were born in 1900 79 per cent would have died before reaching retirement. Today 48 per cent may expect to reach age 65 years In 1900, 77 per cent of the white babies born in 1900 would not have survived to 75 years of age, and only 10 per cent of the Negroes born in that year would have lived 10 years beyond the age of retirement Today, that is, in 1959, 48 per cent of the whites and 30 per cent of the Negroes may expect to live to the age of 75 years

In comparison with older men, older women have increased, to a certain extent, their rate of participation in the labor force Between 1900 and 1950 this rate rose slightly from 8 3 to 9 5 This is a very recent change, for the rate of female participation actually declined from 8 3 to 6 7 between 1900 and 1940 Since World War II the rates for women of *all* ages have gone up A general change in the labor market, a diminution of work involved in routine household tasks due to the increased use of labor saving devices and prepared foods, a decrease in the size of the average household and a noticeable secular trend in female work orientation have contributed to the rise in the labor force participation rate of women

There can be no doubt that the decline of older males in the labor force is explainable on the basis of the decreasing economic importance of agriculture and self employment in the national economy, changes in the labor market and the other reasons discussed so far The self employed, whether farmer or professional, often continue to work well past the retirement age, even if only on a part time basis

With fewer farmers in the population and the increased organizational employment of professional people and labor, the opportunity for staying gainfully employed as an old person has grown much smaller It is becoming standard practice for both management and labor in industry and commerce to retire employees at the age of 65 or at a fixed earlier date At the same time many more older people today seem to have come to accept the idea, often reluctantly, that "voluntary" retirement at a certain point in one's working life is the socially desirable thing to do

Self employment —Actually, more elderly persons than younger workers are self employed In 1952 only 16 per cent of the total labor force was self employed, 82 per cent were wage and salary workers (Table 10) Yet 40 per cent of all workers 65 years and over were self employed, and the proportion of self employed climbs be

yond 50 per cent among people 75 years and over

This relatively large number of self employed older workers is heartening and has been credited to two facts Self employed persons are able to be more flexible about their retirement age, and many workers have accumulated sufficient capital to go into business of their own after retirement Nevertheless, we must consider the following If self-employment as a whole is on the decline, yet proportionally more older people are self employed workers, they are, in fact out of step with the total work pattern This exposes them as a group more acutely to the inherently greater economic risks and difficulties in self employment It is a moot question of how well their previous work experience prepared them for this and how well they can face it during their years of increased physical and symbolic losses

Occupational distribution —Certain major occupational changes have taken place in the United States since 1910 The relative proportion of skilled workers, foremen, and professional persons increased only slightly between 1910 and 1950 (Table 11) The change is only about 2 and 3 per cent, respectively During the same period a significant decrease occurred in the job category of proprietors, managers, and officials and that of unskilled workers These categories dropped from 23 per cent of the labor force to 16 per cent, and from 36 per cent to less than 20 per cent, respectively Concurrently, the relative proportion of clerical and sales personnel has doubled, and the category of semiskilled workers has become significantly more important in the total employment picture

The 1952 data make it clear that the largest proportion (61 per cent) of people aged 65 and over are in the two occupational categories whose relative importance markedly decreased during the years since 1910 (Table 11) Only 21 per cent are employed in clerical and semiskilled positions, although the importance of these occupational categories increased the most during the same period of time The remainder hold positions in the total labor force that reveal only a negligible increase in importance since 1910

Perhaps there is some consolation for the aged in the fact that more of those past the age of 65 hold managerial positions than any other age group between 45 and 54 or 55 and 64, the age span when people are supposed to fulfil the American ideal of climbing the occupational ladder successfully On the other hand, the existence of a disproportionally high representation of persons over 65 in a job category of declining importance in the over-all employment picture, but with a relatively high degree

TABLE 10*

CLASS OF WORKER OF EMPLOYED PERSONS BY AGE, 1952
(Per Cent)

Class of Worker	Age of Worker			
	14 and Over	45 54	55 64	65 and Over
Wage and salary worker	82	78	74	59
Self-employed	16	20	25	40
Agriculture	7	7	11	21
Other	9	13	14	19
Unpaid family workers	2	2	1	1

* Source U S Committee on Aging and Geriatrics (1952) p 56 Data from U S Bureau of the Census *Current Population Reports Labor Force* Series P 57 No 11 and unpublished data.

of decision making potential, may contribute materially to the already existing cleavage and conflict between entrepreneur and labor and older workers and younger workers in general

Manpower obsolescence —It is especially important to consider these interpretations with reference to the outlook of the younger generation, who often tend to overlook the other, less favorable side of the employment coin of the aged Their immediate concern over seeing ' so many ' older men in the managerial saddle obscures the fact that a disproportionately large and nearly equal part of people 65 years and over work as unskilled labor However the reported changes in the occupational distribution do not suggest that the competitive position of older workers has been generally weakened by a progressive reduction of the use of manpower in production

The historic decline in labor force participation among older persons has often been attributed to the increase in mechanization and assembly line production which requires younger and stronger physical specimens rather than the more seasoned or experienced older person Regardless of the relative increase or decrease in the importance of major occupation categories a typical career in any one of them entails shifts from one job category to another with increasing age Furthermore while it is true that in terms of work experience a goodly number of older men know obsolete skills in the light of the current occupational picture there is no clear evidence that a contraction in a given job classification displaces more older people than people of all ages (Sheldon, 1958)

A case in point is the managerial job category where the contraction of opportunity appears to have been felt more by younger people In the skilled work area older people also seem to have remained in a more strategic position to hold on Apprenticeship regulations existing in craft unions, for example tend to militate against the categorical displacement of older workers The obsolescence hypothesis, while not disproved is not fully supported by the available evidence It is likely that, with the progress and spread of automation, the older worker if he availed himself of the proper training will enjoy a greater variety of job opportunity than at present and a greater job security than the younger worker with less training and experience

Educational status —For a full understanding of the labor force participation differential between the older and younger population it is necessary to mention the

TABLE 11*

PERCENTAGE DISTRIBUTION OF MAJOR OCCUPATION GROUP UNITED STATES FOR SELECTED YEARS

Major Occupation Group	1910	1930	1950	January 1952†			
				14 and Over	45–54	55–64	65 and Over
Professional persons (inc technical and kindred workers)	4 4	6 1	7 5	9	10	7	8
Proprietors managers and officials (inc farm)	23 0	19 9	16 3	16	21	24	32
Clerical, sales and kindred	10 2	16 3	20 2	20	16	14	11
Craftsmen (skilled workers) and foremen	11 7	12 9	13 8	14	15	16	10
Operatives and semiskilled workers	14 7	16 4	22 4	21	19	17	10
Unskilled workers (inc service workers and laborers of all kinds)	36 0	28 4	19 8	21	20	21	29

* Source U S Bureau of Labor Statistics 1952 p 19 U S Committee on Aging and Geriatrics (1952) p 56
† Detail may not add to total because of rounding

role that educational status plays in this According to a variety of comparisons, based on 1950 data, the aged have had less formal schooling than the adult population as a whole (U S Committee on Aging and Geriatrics 1953 Shock, 1957) More elderly persons than adults as a whole attended no school, a larger percentage only attended elementary school and a minority obtained a full high school or college education In other words, when our grandparents were children schooling was not accorded the social and economic importance it has since acquired Not many children went on to high school, and higher or specialized education was more related to economic affluence than occupational need

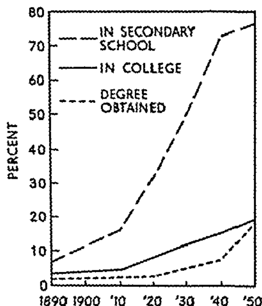


Fig 7 —Percentage of young people 14–17 years old in secondary school of those 18–21 in higher education of those 21 obtaining a college degree (After Pressey and Kuhlen 1957 p 167 data from U S Office of Education *Statistical Summary of Education* [Washington D C Government Printing Office, 1953] chap i pp 19 38 39)

Figure 7 provides a graphic picture of the steep increase in the amount of secondary education received by the general population since 1890 Despite the fact that the drop-out rate before graduation has not improved since that date, more than 75 per cent of all people aged 14–17 were in secondary school in 1950 In 1890 little more than 7 per cent of the teen age population spent their later adolescence in school. During the same period participation in college life for young people between the ages of 18 and 21 increased from 3 to nearly 20 per cent

In 1950 people aged 65 years and over had received a median of only 8 2 years of formal education, whereas half of those aged 25–29 had completed 12 1 years of schooling Census data (Fig 8) show that about one in every five persons aged 65 and over failed to complete 5 years of schooling or had no formal schooling whatsoever Only about a fourth had a high school education, and less than one in ten aged persons ever went to college

This picture has brightened some in the last decade, especially for people aged 45 and over and is likely to improve more in the future because of the expansion of educational facilities and an increased emphasis on formal schooling However, the present generation of older people do find themselves adversely affected in seeking and holding jobs whenever rather rigid educational levels are required as part of the job qualifications (Stabler, 1957) In other words, according to current standards and job requirements, the aged as a group are in an unfavorable position when compared with the increasing number of young persons entering the labor market at age 18 years and over today It may be possible to say that this is another situational factor which has contributed to the contemporary cult of youth in general and in the labor market in particular

Financial resources—As one might expect, the individual income cycle is a phenomenon associated with increased age Census data of 1950 (Table 12) show a progressive decline with advancing years for both men and women Apart from the fact that the median income for women is lower than that of men, and the proportion with low income greater, the income distribution for both sexes according to age is

similar The earning level of men 65 years and over in terms of median income, is almost one third of their level of earnings during the period of 35–44 years of age

From ages 14 to 45 the proportion of males with an income of less than $2000 shows a consistent decline Thereafter, this proportion increases steadily, until it reaches nearly 80 per cent among male heads of families 75 years and over (Sheldon, 1958) Only a very small group of individuals continue to enjoy the benefits of a high income level into an advanced age (Table 13)

In general, families with an aged head have low incomes If the family head is still working, he is past his period of peak earnings, if he has retired his income tends to be even lower Thus a comparatively large number of families with an aged head depend on old age assistance of one form or another The data show (Table 13) that in 1950 about half the families with a head 65 years and over had an income below $2000, and three in every ten such families took in less than $1000 per year The plight of the unrelated individual 65 years and over who lives alone was even more bitter More than three-quarters of them (76 5 per cent) had incomes of less than $1000, hardly enough to maintain an adequate level of living

Clearly, the level of disposable income is adversely affected by increased age The major reason for this, of course, is the decrease in labor force participation with age (Table 14) On the other hand the proportion of people with no income does not increase at the rate that the proportion of people not working increases In fact, after age 65 the former decreases, while the latter continues to rise Regardless of the consoling phenomenon of social security benefits in old age, there is a sizable difference between the median income of those who work and those who cannot past the age of 65

Among older persons 65 years and over, a decreased level of disposable income is associated with a diminished difference between current income and the total of current expenditures (Table 15) Not only do

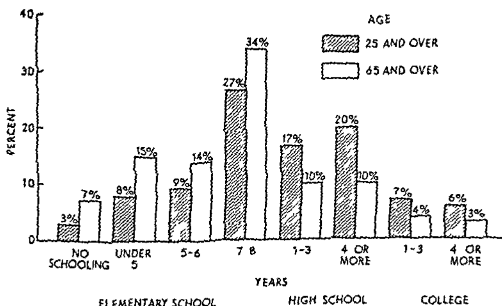


FIG 8 —Years of school completed percentage by age groups 1950 (From U S Bureau of the Census 1950, *Census of Population*, Preliminary Reports Series PC 7 No. 6)

they save a smaller part of their income than people in the early and middle years but they also tend to show a lower total indebtedness including mortgages These differences as well as their relatively higher net worth or favorable difference between total reported assets and total reported debt, are a function of the spending saving pattern which changes with age

In general older people no longer incur comparatively large debts such as result from the purchase of a home and furnish

TABLE 12*

MEDIAN INCOME OF PERSONS WITH INCOME IN 1949 AND PER CENTAGE WITH INCOME OF LESS THAN $2000 BY AGE AND SEX

Age	Male		Female	
	Median Income	Per Cent less than $2000	Median Income	Per Cent less than $2000
14 19	$ 435	93 6	$ 419	95 3
20-24	1669	59 4	1276	75 8
25 34	2737	29 4	1309	69 1
35-44	3073	24 7	1358	67 2
45 54	29"9	28 3	1316	67 5
55-64	2551	37 0	1006	75 0
65 and over	1128	68 0	602	89 1
Total 14 years and over	$2434	39 8	$1029	74 7

* Sou ce Sheldon (1958) p 113 U S Bureau of the Census 1953) Table 139

TABLE 13*

INCOME LEVEL (PER CENT) OF FAMILIES BY AGE OF HEAD AND OF PERSONS LIVING ALONE BY AGE 1950

Income†	All Families‡	All Persons 14 and Over Living Alone§	Age			
			55 64		65 and Over	
			Head	Alone	Head	Alone
Under $500	5 8	27 8	6 6	26 7	14 7	39 1
$500-$999	5 7	21 3	6 1	19 9	15 7	37 4
$1000-$1999	13 2	18 8	14 6	22 1	21 2	12 9
$2000-$2999	17 8	16 4	17 8	14 3	15 8	5 3
$3000-$3999	20 7	10 2	16 8	11 4	11 5	2 1
$4000-$4999	13 6	3 1	13 3	2 7	6 4	6
$5000-$5999	9 0	1 2	7 1	1 4	4 4	7
$6000-$9999	11 0	1 0	13 1	1 1	7 1	1 4
$10,000 and over	3 3	4	4 8	4	3 2	5

* Source U S Bureau of the Census (1950)

† From wages or salary net earn ngs f om self-emp oy ment, nterest div dend rents social nsuran e and public and private assistance and contribut ons, ncluding ncome in kind.

‡ A group of two or more related persons by blood, marriage, or adoption residing together

§ Or w th non-relati es

ings. They do not have to pay any more insurance premiums for retirement benefits, many have paid off their mortgage indebtedness, and the need for the replacement of capital goods, including automobiles, has grown smaller Lest this convey the idea that the position of the aged in terms of their low average individual cash value is not too distressing, the reader is reminded of the fact that the majority must pay a heavy price for these advantages

Not only is the income of most aged persons lower but both its source and its amount are generally fixed Since a proportionately larger amount of their income must go into securing consumables, like food and fuel and, above all, medical care and drugs, many aged find themselves unduly constricted in meeting the rising costs of an expanding economy to maintain an adequate level of living

The prolongation of life and the maintenance of health have traditionally been the fervent wish of all men and the hallowed goal of medicine in particular Ironically, however the increasing success in extending the individual's life span through medical means and public health advances is creating a new and taxing problem The chronic progressive disorders of later life are becoming more prevalent and are creating the prospect of a prolonged medicated or severely disabled survival for a mounting number of aged persons

This problem bids well to place a continuously rising burden on the health, nursing and domestic and economic and social resources of every community, for it threatens each aging individual with the prospect of an increase in the "average duration of final incapacity," when the younger generation must carry the old (Sheldon, 1954)

TABLE 14*

MEDIAN INCOME OF PERSONS WITH INCOME IN 1951 BY LABOR FORCE STATUS AGE AND SEX

Age	Male		Female	
	In Labor Force	Not in Labor Force	In Labor Force	Not in Labor Force
14 24	$1731	$ 344	$1357	$415
25–64	3361	1082	1830	578
65 and over	2121	774	850	506
Total 14 and over	$3155	$ 718	$1695	$502

* Source Sheldon (1958) p 116 U S Bureau of the Census (1950) Table 4

V Effects of Changing Health Patterns

So far we have discussed some of the outstanding socioenvironmental and demographic aspects of the lengthening of man s life span Our broad understanding of the sociocultural background of the aging individual would not be complete without a careful assessment of some of the important socioeconomic implications of patterns of health and disease in old age

DISEASE AND AGE

While we shall stress the above problem in our discussion, it is necessary that we distinguish old age and progressive normal age changes and waning activities from disease Even persons with healthy constitutions experience major age changes that they share with the less healthy They appear at different age levels in the individual and in separate organ systems, and they do not seem to result from specific diseases.

TABLE 15*

INCOME SAVED HOMEOWNERSHIP, ASSETS, INDEBTEDNESS AND NET WORTH OF SPENDING UNITS BY AGE OF HEAD 1950 AND 1951

Item	Per Cent of Units Falling in Specified Group	
	All Spending Units†	Spending Units with Head 65 Years of Age and Over
Per cent 1950 income saved‡	100	100
50 or more	4	5
10–49	33	21
1–9	24	20
None	7	19
Negative savings	32	35
Homeownership 1951	100	100
Own home	54	65
Pay rent	41	30
Other	4	5
Total assets 1950§	100	100
Under $1000	31	26
$1000–$4999	22	13
$5000–$24 999	37	44
$25 000 and over	8	15
Not ascertained	2	2
Total indebtedness 1951‖	100	100
None	41	71
$1–$500	27	14
$501–$5000	21	10
$5001 and over	9	2
Not ascertained	2	3
Net worth 1950#	100	100
Negative	8	1
$1 $999	27	26
$1000–$4999	23	15
$5000–$24 999	32	42
$25 000 or more	8	14
Not ascertained	2	2

* Source U S Committee on Aging and Geriatrics (1952) p 52 Data from Survey of Consumer Finances Federal Reserve System *Federal Reserve Bulletin* December 1950 pp 1588 1591 July 1951 p 772 September 1951 p 1063 December 1951 p 1517

† A spending unit is a group of persons living in the same dwelling and related by blood marriage or adoption who pool their incomes for major items of expense

Although there are progressive degenerative changes, the senescent person is seldom "old" throughout, and individual variation in or lack of uniformity in physiological aging is much greater in older persons than in younger ones (Lansing, 1956)

The fact remains, however, that more and more people in the population must live with and adapt to the typical physiological signs of becoming old In their efforts to maintain a functional health level they must contend with a significant increase in the impairment of specific function, like hearing, as well as changes in their reaction to severe stresses Most older persons, for example, show the common and normal signals or symptoms of disease less than younger people, because stress produces less severe reactions in them (Selye, 1956, Hinkle and Wolff, 1957) The inherent dangers of this to the maintenance of healthy functioning are obvious

Chronic illness—The significant rising incidence of the so-called degenerative chronic illness and of the associated mortality rate in the aged population since 1900 must be evaluated against the background of the significant increase in the number of older persons who all share in the progressive signs of normal physiological aging

The chronic diseases that are progressive or have a slow recovery rate may befall all ages They are only more characteristic of the older age groups Further acute illness with rapid recovery is not the exclusive experience of younger age people Finally, the majority of chronic diseases of later life arise in middle life Dying from these diseases is more common only in late life Of those who are chronically ill, more than 75 per cent are between 15 and 64 years old, and 50 per cent are under 45 years (Sheps, 1957, p 134)

§ Total assets include liquid assets (savings accounts, checking accounts government bonds and shares in savings and loan associations and credit unions) automobiles owner occupied

Net worth is the difference between total selected reported assets and total reported debt

Keeping in mind that no disease is so specific as to be found exclusively in late maturity, we are now ready to examine the changes in the patterns of disease and of impairment of specific physical functions in old age and their relation or threat to normal socioenvironmental adaptation We begin with a discussion of the continuously rising incidence of chronic disease as a well nigh universal risk of a longer life span (Table 16)

We recall that since 1900 the life expectancy of white males rose about 20 years and that of females 23 years This was largely accomplished through medical advances primarily affecting the younger age groups and improved living conditions for all (U S Department of Health, Education, and Welfare, 1957*a*, 1957*b*) However this phenomenon has been accompanied by significant shifts in the population incidence of specific diseases and in the eventual causes of death Put in simple terms, a longer life span means more chronic disease and becoming increasingly liable to limitations of normal functioning (Table 16)

The group of diseases we are talking of have been referred to as 'chronic progressive disorders of later life" (Stieglitz, 1950) They are discussed in chapter xi of this handbook In the long run, all of them entail a high risk of severe physical disability and therefore constitute a grave threat to normal socioenvironmental participation

Cause of death—While the causes of disease among the younger age groups are most often exogenous, specific, and of recent occurrence, the etiology of diseases of late maturity are usually endogenous, multiple cumulative and progressive Thus, since 1900 the dominant disease pattern and the associated leading causes of death have changed from the high incidence and prevalence of communicable diseases and resultant mortality rates to those of the degenerative or chronic diseases today (Health Information Foundation, 1957*e*, p 2)

The extent of chronic illness, the increase in death rates therefrom, and the long term toll of disability can be gauged if we consider that in 1875 chronic diseases caused one fifteenth of all deaths and in 1950 as much as three fourths Now it causes 60 per cent of all disability and 80 per cent of the deaths In other words, more than three quarters of deaths today represent terminal events from long term illnesses (Switzer and Rusk, 1952, Sheps, 1957, p 134)

We can readily see from Table 16 that in the older age groups the most common affliction is chronic illness Whereas 70 8 per cent of all people under 15 years of age have *no* chronic illness, 95 4 per cent of people living beyond retirement age suffer from chronic disease conditions Only 1 1 per cent of the age group of 15–34 years, a period encompassing some of our most sig-

TABLE 16*

LONGER LIFE SPAN AND RISE OF CHRONIC DISEASE

(Per Cent)

Disease Conditions	All Ages	Age Group			
		Under 15 Years	15 34	35 64	65 and Over
With limitation of activity	4 3	1 2	1 1	4 1	29 9
Substantial chronic conditions	44 4	17 4	31 0	65 9	85 2
Chronic conditions	64 9	29 2	63 5	85 8	95 4
No chronic illness	35 1	70 8	36 5	14 2	4 6

* Source Adapted from Parke Davis & Co (1958) p 3

nificant social and economic activities suffer from diseases that limit activity On the other hand 29 9 per cent of people aged 65 years and over have to learn to live with such disease conditions Moreover almost two and three quarter times as many of these persons than people in the 15 34 year age bracket have to contend with disease conditions that have been classified 'substantially chronic that is conditions that in the examining physician s judgment actually or potentially are disabling or require medical attention (Commission on Chronic Illness 1957)

related to the decline of mortality in general rather than to any substantial increase in mortality from cardiovascular renal d s eases as a group (Health Informat on Foundation 1957*c* p 1)

Regardless of this the fact remains that the aging person today faces the necessity of adjusting himself to the unavo dable and increasing risk of eventually succumbing to a degenerative disease and prolonged physical disability In other words his life is not as likely to end suddenly because of too much external activity accidents or exogenous disease as it is likely to end slowly

TABLE 17

DISEASES TAKING GREATEST TOLL AMONG AGED*

Cause of Death	Per Cent of Dea hs	No of Deaths at 65 and O er		
		To al	Ma e	Female
Heart	69	401 612	214 831	186 781
Vascular les ons affecting central ner ous s stem	76	133 699	63 184	70 515
Mal gnant neoplasms	52	125 995	69 044	56 951
General arteriosclerosis	94	30 571	14 866	15 705
Influenza and pneumon a	53	23 373	12 460	10 913
Diabetes	63	16 149	6 047	10 102
Chron c neph i s	55	8 01	4 518	4 183
Hype tens on w thout heart nvolvement	69	7 696	3 743	3 953

Sou e Adapted f om Pa ke Da s & Co 1958 p 3

To a large extent the shift in the leading causes of death from the communicable diseases to the degenerative diseases of to day and the rise in the death rates for diseases such as diabetes heart disease vascular lesions and malignant neoplasms reflects only the increasing proportion of people who *live long enough* to develop such conditions (Dublin 1951 Collins *et al* 1955*b* U S Department of Health Education and Welfare 1957*a*) Thus today cardiovascular disease claims more lives than all other diseases combined in the older aged population (Table 17) Between 1900 and 1956 mortality from the major cardiovascular renal diseases rose by about 50 per cent In other words it appears that the rise in their proportion to the total is on account of progressive internal decay Without a doubt the adequate emotional and environmental handling of such losses requires more personal skill and ability than many of us can reasonably learn or hope to possess when the time comes

SEX DIFFERENCE IN MORTALITY

This discussion would not be complete if we did not consider the relationship of the shift in the lead ng causes of death today with the known and widening d fferential between male and female mortality In 1956 there were 228 000 excess male deaths in the country The annual differential has been over 100 000 since before 1933 and more than 200 000 since 1950 (Health Information Foundation 1957*e*)

We have learned that women have benefited more than men from the general decline in mortality and that even at the turn of the century they were in a more favorable position in this respect Although the extent of mortality decline has always varied widely by age, since 1900 the margin of difference between the sexes has increased greatly at all ages except during infancy and at age levels over 85 years

Actually, excess male mortality is typical of almost all leading diseases In 1900 three of the *then* leading causes of death—tuberculosis, pneumonia and influenza, and diarrhea and enteritis—resulted in a small excess of mortality for men By 1955, when through medical advances the importance of these diseases declined, their effect on the sex ratio for all deaths was negligible, even though excess male mortality had risen sharply in the interim Indeed, the shift in the leading disease causes of death has significantly contributed to the widening differential Table 17 gives us a glimpse of some of the differentials prevailing for people aged 65 years and over For example, older men lead older women in succumbing to fatal cardiovascular afflictions Heart disease causes more than one half of the total mortality differential at ages 40–74 years In 1900 heart disease only caused an excess of male mortality of 11 per cent but, by 1955, the over all differential rose to 78 per cent (Health Information Foundation, 1957*e*)

In addition to facing greater hazards from cardiovascular disease, more aged men today succumb to cancer than women (Table 17) Around 1900 cancer only caused 4 per cent of *all* deaths among men and women of all ages Moreover 65 per cent more women than men died from this disease By 1955, however, this situation had reversed itself, and 20 per cent more men died from cancer, and in particular men under 29 and over 55 years of age This excess mortality is in part due to the fact that men at the older ages seem more vulnerable than women to cancer of the respiratory and digestive systems (Health Information Foundation, 1957*e*)

The only major chronic disease risk that is greater today for women than for men is diabetes (Health Information Foundation, 1958*b*) The dangers of final incapacity and death from this specific disease have been greater for women of all ages, and the differential has widened since 1900, especially in the upper age groups However, because in 1956 less than 2 per cent of all deaths have been attributed to diabetes, it has little effect on the total mortality situation A glance at Table 17 will confirm this finding Almost 36 times as many men, and about 19 times as many women, died from cardiac diseases than from diabetes

URBANIZATION AND MORTALITY

There are some significant socioenvironmental aspects of the sex differential in the ability to survive disease It seems that the higher the degree of urbanization of a given area the wider is the mortality differential between the sexes This in turn appears to be in part related to some geographic variation in mortality On the whole, the Western States of the United States have the best record, with the rural West North Central division leading in 1957 with 7 5 deaths per 1000 population The predominantly urban and industrial Northeast lags behind with the Middle Atlantic States having the country's highest mortality rate, 8 7 deaths per 1000 population in 1957 On the other hand, the South and especially its most rural subdivisions, the East South Central States (8 4 per 1000), also show a high mortality rate (Health Information Foundation, 1958*a*)

In general, regional differentials, owing to variations in available and accessible health resources, in levels of living and special demographic characteristics, and in the new environmental hazards of life in metropolitan areas, tend to overshadow rural urban contrasts as such Health conditions within the cities themselves are subject to great variations, and rural urban differences in the extent of disabling illness are rather small (Woolsey, 1952, Lowell, 1956) A re-

among women The visit rates for women of 65 years and over were almost twice those for men over 65 years and those for women of all ages (Table 18) On the other hand it has been reported that more men than women in the United States were hospitalized patients in 1953 (Dickinson, 1955 Fraenkel and Erhardt 1955, Dickinson and Raymond 1956 Health Information Foundation 1958d) The adequacy of figures on hospitalized morbidity and morbidity in general will be raised later

TABLE 18*

ESTIMATED NUMBER OF DOCTOR VISITS† PER 100 PERSONS PER MONTH ‡ CALIFORNIA HOUSEHOLDS BY AGE AND SEX 1955

Age	Total	Men	Women
All ages	40	35	40
0–14	30	29	31
15–44	38	34	41
45–64	48	41	54
65 and over	61	42	79

* Source California Department of Public Health Bureau of Chronic Diseases (1955) Tables I III IV

† Excludes newborn and maternity visits

‡ Based on 28 days of observation between January and May 1955

When family income is kept constant a pattern of increase with age in use of medical services is also revealed (Table 19) In a similar comparison (Table 20) of older persons with those of all ages who as members of a health insurance plan experience no barrier to receiving actually needed physician s services, doctor utilization rates per 100 enrollees for people of 65 years and over amounted to 728 as against 509 for people of all ages This represents an increase of 43 per cent

Of more interest from the point of the increased impact of physical disability on the aged is the fact that in this study the rates of physician visits *in* the hospital were 140 per cent higher among the aged than for those of all ages Moreover, the rate of office visits among the aged was a third again as high than the rate for all ages Only home visits were made in approximately equal amounts to older people and to those of all ages (Table 20)

Variations in the degree of utilization of physician s services have also been found to be related to differences in income level Available data indicate the likelihood of poorer health conditions and of the receipt of free care in the lowest economic group Steiner and Dorfman (1957) found that free care or care involving no out-of pocket expense was provided most often to people with an income of under $2000 In the California household survey the highest rate of doctor visits, 75 per 100 persons per month, was scored by people past 65 years who were in the lowest income group (Table 19)

TABLE 19*

ESTIMATED NUMBER OF DOCTOR VISITS† PER 100 PERSONS PER MONTH ‡ CALIFORNIA HOUSEHOLDS BY FAMILY AGE AND INCOME 1955

Age	Family Income		
	Less than $2000	$2000–$4999	$5000 and Over
All ages	43	39	41
0–14	22	30	32
15–44	23	40	40
45–64	42	50	49
65 and over	75	39	69

* Source California Department of Public Health, Bureau of Chronic Diseases (1955) Tables I, III, and IV

† Excludes newborn and maternity visits

‡ Based on 28 days of observation between January and May 1955

Health insurance —When a comparison is made of the number of doctor visits by people carrying health insurance with that of people without health insurance, it can be shown that older people with insurance see physicians more frequently This seems to indicate that families with only their own resources to pay medical bills are

economically deterred from seeking medical services even if needed (Table 21)

Economic status —It has been said that *ownership of health insurance in the age* group 65 years and over implies a better economic status and the enjoyment of better health This needs clarification On the one hand, we learn that people over 65 years with an income of $5000 and over make fewer doctor visits and are likely to be in better health than people over 65 years with an income of less than $2000 On the other hand, we learn that people over 65 *years with an income of over $5000 visit* the physician more frequently than people in the lower-income brackets Presumably, they are in a better position to do so because *they can afford health insurance*, whereas the poorer income groups cannot do so because they are not insured

The best answer seems to be somewhere between this apparent contradiction People in the lower-income groups on the whole seem to reveal lower age specific rates of doctor visits up to retirement age and especially in the age range of 15–44 years (Table 19) This is significant, because it *is during this period that much of the* groundwork is laid for the degenerative diseases of old age In other words, even if people in these lower income groups experience an actual and "felt" need for seeing a physician that may equal the need of those who visit physicians more often throughout the life span, they cannot afford to satisfy this need Thus they get into more health difficulties in late maturity and actually have to visit a physician more often on a free care basis, regardless of whether they have health insurance or not

The general finding of progressive increase in the frequency of medical attention as people become older and of height*ened morbidity among women is confirmed* by results of the Wolverhampton Survey (Sheldon, 1950) Figure 10 shows that

TABLE 20*

RATES OF SEEING DOCTOR PER 100 ENROLLEES BY PLACE OF SERVICE 1954†

PLACE OF SERVICE	ALL AGES		65 AND OVER	
	No per 100	Per Cent	No per 100	Per Cent
Office	396 8	78 0	539 3	74 1
Home	56 4	11 1	55 1	7 6
Hospital	55 5	10 9	133 6	18 4
Total	508 7	100 0	728 0	100 0

* Source B ewster and McCamman (1956) p 63 Data from Division of Research and Statistics, Health Insurance Plan of Greater New York 1956

† Based on a 10 per cent sample of Health Insurance Plans population

TABLE 21*

ESTIMATED NUMBER OF DOCTOR VISITS† PER 100 PERSONS PER MONTH ‡ CALIFORNIA HOUSEHOLDS BY HEALTH INSURANCE COVERAGE AND AGE, 1955

Age	No Health Insurance	Some Health Insurance
All ages	37	43
0–14	27	33
15–44	33	41
45–64	42	52
65 and over	58	69

* Source California Department of Public Health, Bureau of Chronic Diseases (1955) Tables I, III and IV

† Excludes newborn and maternity visits

‡ Based on 28 days of observation between January and May 1955

men and women show a similar trend up to the age of 70 years, after which the difference increases that is, women begin to need relatively more treatment and men relatively less This means not only that more women survive than men with advancing age despite a greater incidence of ill health but also that more women than men will have to be concerned with the physical care of the really aged

COST OF MEDICAL CARE

Some important socioenvironmental questions can be raised about the relationship

per cent of the population, they incur 13 per cent, or about $1,591,200,000, of the total annual costs (estimated at around $12,250 000 000) for all private personal health services Furthermore, direct public spending on health services for the aged is equal to one eighth of the total health costs of caring for the aged or about $200 000, 000 (Anderson and Feldman, 1956, Health Information Foundation, 1957*a*, Parke, Davis and Company, 1958)

Experience under a Blue Shield Plan with the relative costs of surgical and medical claims made by people of 65 years and

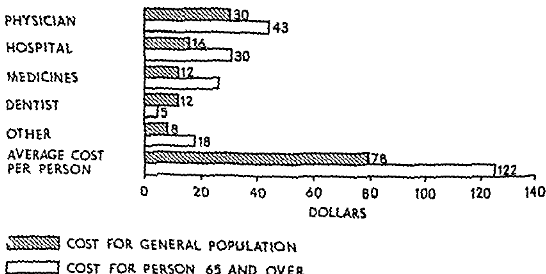


FIG 11 —Cost of medical care for aged United States 1948 (After Parke Davis & Co 1958 p 5)

between the morbidity of the aged and the cost of medical care Figure 11 clearly shows the increased cost burden befalling the aged in four major types of personal health services Indeed, the average annual cost for a person 65 years and over amounts to $44 more than for the general population The economic implications of this apparently normal experience for retired persons are clear (Fig 11)

The magnitude of the economic and social problem of maintaining a reasonably adequate level of health in old age can be appreciated if we consider this Although the United States aged comprise only 9

over sheds additional light on the social and economic problems of heightened morbidity On the average, surgical claims for single aged men reached more than twice the average cost for men of all ages and in hospital medical claims were more than three times as high The single aged women by comparison, incurred less cost in the medical service category However, their medical claim cost topped single aged men by a good margin (Table 22)

Of considerable socioenvironmental significance is the fact that neither the surgical nor the medical cost claim experience with married couples past the age of 65

years was very high Again women showed a higher in hospital medical claim pattern than men Men were higher in surgical claims Nevertheless, two inferences can be drawn (1) hospitalization is less needed if a spouse is present in the home and (2) the age of couples is on the average lower than that of single persons For this reason, the sex linked morbidity differential does not play as significant a role, nor have these persons lived as yet long enough for illness to ripen into terminal disease requiring more medical service

TABLE 22*

PERCENTAGE RELATIVE CLAIM COSTS AT AGES 65 AND OVER TO CLAIM COSTS FOR ALL AGES COMBINED AS REPORTED BY UNITED MEDICAL SERVICE INC OF NEW YORK

TYPE OF CONTRACT	RELATIVE CLAIM COSTS†				PERSONS 65 AND OVER AS PERCENTAGE OF ALL AGES
	Surgical		Medical		
	All Ages	65 and Over	All Ages	65 and Over	
Single					
Men	100	208	100	354	5 1
Women	100	134	100	381	2 8
Two person					
Men	100	123	100	124	13 8
Women	100	89	100	169	6 3
Family					
Men	100	‡	100	‡	0 2
Women	100	‡	100	‡	

* Source Hunter and Coleman (1954) pp 6–27 Table 11
† Obstetr al claims excluded
‡ Incomplete data

BIASES OF SURVEY METHODS

The foregoing discussion of morbidity frequency of medical attention, and cost of medical care raises some questions about the validity and generality of the inferences that we drew Household surveys tend to be subject to a variety of biases such as underreporting and overreporting that may be selective for sex (Health Information Foundation, 1957e, p 5) Women usually are the chief respondents in such surveys, and they may remember their own illnesses better Studies of physicians in private practice tend to disregard the growing physician population associated, for example, with the Veterans Administration Finally, studies of hospitalized morbidity often are incomplete because they have insufficient data on admission rates and length of hospital stay Also reported regional and rural urban variations and educational and economic differences in the use of general hospitals would tend to influence any generalizations about hospitalized morbidity *in the United States* (Committee for the Special Research Project in the Health Insurance Plan of New York, 1957, Odoroff and Abbe, 1957)

Regardless of these caveats in interpretation of the data on hospitalized morbidity, it can be said that the evidence presented about medical care cost patterns are uniform enough and available on a nation wide basis to allow us to give high credence to the inferences we have drawn Moreover, the data obtained from research in

England and the United States do coincide regarding the differentials in the morbidity patterns As long as we remember that there exist specific variations within these differentials we have no reason to doubt *the over all patterns that have been shown* Among these are the higher surgical morbidity for males than for females, who because of economic and social pressures tend to ignore all but the most serious symptoms the high in hospital medical morbidity for females and finally the fact that the increase in the over all morbidity differential occurs largely past the age of 70 years

TABLE 23*

SPECIFIED UNMET NEEDS OF PERSONS 65 AND OVER IN CALIFORNIA

Specified Unmet Needs	Per Cent with Specified Need
Medical care and drugs	14
Clothing	12
Dentures	8
Glasses	6
Telephone	6
Household equipment	4
Hospital care	3
Housing	3
Laundry	2
Other utilities	2
Hearing aid	1
Other	1

*Source Bond *et al* (1954) p 34

UNMET NEEDS OF THE AGED

We often talk about the many unmet material needs of the aged that tend to compound their already difficult problem of making an adequate socioenvironmental adjustment to their inevitable physical and biological losses In order to gauge the aged's real potential of adaptation to the so called normal progressive age changes that impede many normal specific functions, it is useful to have some yardstick even if inadequate about what they consider to be their most frequently unmet needs Data from a 1952 California survey can provide us with at least a partial answer.

According to this survey of persons at or beyond the retirement age, the most frequently mentioned unmet need was medical care and drugs In the light of previously cited findings, this should not come as a surprise *Also of note is the expressed* need for such items of health maintenance as dentures eyeglasses, hearing aids, and hospital care (Table 23)

Without a doubt, many aged must engage in an unnecessarily hard struggle to continue to present a reasonably intact face and body to society Their experience of being different or even deviant from the active younger people around them and their experience of growing more distant from the ongoingness of things can only *increase* if their needs for eyeglasses, dentures hearing aids, and adequate clothing remain unmet for long

We might argue that these problems are faced only by a small fraction of the total aged populations, namely the social isolates and those in dire financial circumstances The same California survey of persons 65 years and over reveals that, regardless of the old age assistance status of aged single persons or couples, medical care and drugs remained the most frequently cited unmet needs Next to the need for a more adequate food supply that is mentioned first by receivers of *OAA but* not by the others, clothing dentures, and eyeglasses remained high on the list of the insufficiently met needs of both groups (Table 24)

It is understandable that the likelihood of an increasing number of unmet material needs constitutes a severe, added burden of specific social indignities to many an aged individual It is an added burden because it is so often experienced in conjunction with a continuous increase in the number of "bed days" and 'disability days" This prospect or reality is faced by a majority of the aged, and it constricts the time available for the essential activities of everyday living

EXTENT OF DISABILITY

The seriousness of the problem can be grasped upon examining Figure 12 The average number of days older persons are disabled due to chronic illness and the number of days they have to be bedfast significantly increases with age Persons between the ages of 65 and 74 years, and individuals over 75 years experience almost 2½, and nearly 4 such days, respectively, in any given 4 week period By comparison, all people under 45 years, on the average have less than 1 day in a 4 week period when their powers of move ment are severely curtailed (Commission on Chronic Illness, 1957 Parke, Davis and Company, 1958)

The morbidity difference between men and women is again to be noted in this connection Women show an excess of dis abling illness when they are unable to conduct usual activities for 1 day or longer and when they are confined to bed The Collins Report indicated higher rates for women of 14 and 20 per cent, respectively (Collins *et al*, 1955*a*)

The findings regarding the increased incidence of limited powers of movement or disability days with advancing age are con firmed by the Wolverhampton Survey The random sample revealed that a total of 34 per cent of the aged suffered from some limitation of movement The proportion of aged people with limited powers of move ment grew in relation to any increase in expectation of life at advanced ages, and the ability of unlimited movement declined correspondingly (Fig 13)

While the bedfast aged population (2 5 per cent of the sample) bore little relation to age, 11 per cent of the whole sample were confined to the house. These persons usually required the constant attention of

TABLE 24*

ORDER OF FREQUENCY OF MOST IMPORTANT UNMET NEEDS OF PERSONS 65 AND OVER IN CALIFORNIA BY OLD-AGE ASSISTANCE STATUS

On OAA		Not on OAA	
Couples	Single Persons	Couples	Single Persons
Medical care drugs Clothing Dentures and glasses	Food Medical care drugs Clothing	Medical care drugs Clothing Dentures	Medical care drugs Clothing Food

* Source Bond *et al* (1954) p 261

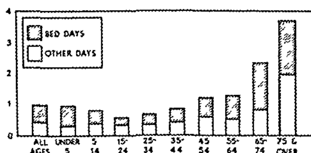


FIG 12 —Bed days and disability days (After Parke Davis & Co 1958)

someone else and often and for various reasons had to impose this domestic problem on the younger generation.

AGE AND SOCIAL DEPENDENCY

The above should not persuade the reader that the over all total of dependent aged has already reached a critical level in contemporary society Although the ratio of people 65 years and over to the working population aged 20–64 years more than doubled between 1870 and 1950, it is still a minor part of the total dependency ratio which also includes all persons under age

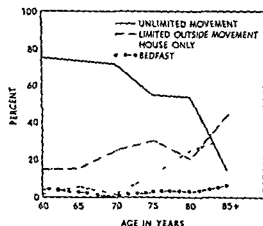


Fig 13 Powers of movement of old people (After Sheldon, 1950)

20 (Table 25) The problem would be very grave today if the population as a whole did not even replace itself or if it increased primarily because of a mounting influx of adult and aged persons Neither condition applies to the United States population at present

Nevertheless, the certain prospect of an ever mounting dependency of the aged on others the longer they live remains an important issue In Great Britain, for instance, an estimated one million old people, or 22 5 per cent of the whole Wolverhampton sample, suffer from a limited capacity for outside movement, the incidence of which rises steadily after the age of 70 years Thus it is of great social importance to any community to have available adequate human and material resources of care to reduce the likelihood of a state of complete dependence of the aged on others *before* this becomes inevitable

The leading causes of limited powers of movement have been listed as the rising incidence of painful feet and vertigo, frequent general weakness and lack of confidence, much dyspnea and arthritis (Sheldon 1950) While all are concomitants of the aging process, painful feet, vertigo, weakness, and lack of confidence are not completely inevitable The severity of the

TABLE 25*

DEPENDENCY RATIOS, UNITED STATES 1870–1950

Year	Ratio No Dependent per 1000 Aged 20 64 Years		
	Total	65 and Over	Under 20
1870†	1113	63	1050
1900†	942	79	863
1940	703	117	586
1950‡	724	140	584

Table II

† Excluding persons of unknown age

‡ Including armed forces overseas

burden they impose on many aged can be attenuated to a considerable degree Primarily, they require more readily available facilities for specific treatment and assistance to reduce the domestic and community problems of care that the premature onset of limitations of mobility implies

Despite illness, old people can function longer than we usually think is possible Therefore, it is important to distinguish normal losses and normal socioenvironmental consequences of the aging process from abnormally disruptive but unnecessary losses and consequences In other words, remedial medical measures for aching feet, for instance, to prevent premature

physical incapacity and appropriate socio economic measures to prolong the independent usefulness and meaningful activity of even the house fast aged are essential to postpone the time of final incapacity and dependence on others This is a major problem for industrial society today

DEPENDENCY AND PHYSICAL LOSSES

Although the subject of specific normal physical losses in old age is discussed in chapter xi a brief mention of it must be made here These losses can and often do lead to unnecessarily severe and early disruptions of socioenvironmental competence

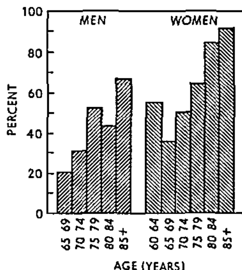


FIG 14 —Difficulty in the dark experienced by old people (After Sheldon 1950)

and effectiveness among the aged We have shown that a most common unmet need among older persons is the lack of hearing aids Progressive hearing loss tends to have a disruptive influence on their relationships with people of all ages and especially younger people It often leads to an increase in general irritability and it is the frequent accompaniment of marked withdrawn behavior

What is even more important about this specific manifest loss is that parallel losses of equal frequency also take place The progressive incidence of vertigo and increased difficulty to orient one s self in the dark are cases in point (Fig 14) Regardless of the transient and mild or prolonged and severe nature of these losses they entail severe psychological and social consequences for many aged people

ACCIDENTS

Apart from tending to enhance a socio environmental fearfulness and watchfulness

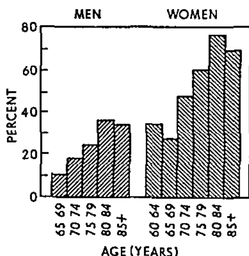


FIG 15 —Liability of old people to falls (After Sheldon 1950)

among the aged these afflictions imply a heightened danger of sustaining physical injury due to accidents or falls (Fig 15) *These in turn may precipitate death or a premature general breakdown of the individual* The subject of home accidents is most relevant to this problem Older people are especially vulnerable since they spend more time in the home either by choice or because of limitations in their power of movement (Health Information Foundation 1957*d*)

According to the Health Information Foundation the problem of home accidents and resultant deaths has been a severe one in American society In 1956 home acci

dents accounted for almost 30 per cent, or 28,000, of all accidental deaths in the United States. The average number of such deaths has hovered around 30,000 each year since 1928. Most important in our context, about 13,600 accidental deaths in 1956 resulted from falls sustained predominantly by individuals of 65 years and over.

Next in importance of fatal home accidents are fire accidents, which took over 5000 lives in 1956. Again aged people, along with children under 5, have the highest mortality rates and represent half of the victims of this form of accident. One of the chief contributory reasons for the high fire accident death rate has been the inability of both young and older victims to act and move fast enough, thus becoming trapped in the fire. While one can accuse many people of being careless about their safety and health, especially in the prime of their life, this is not an appropriate explanation for many aged. On the contrary, the majority are very concerned about these matters, but, for specific physical disability reasons beyond their immediate control, they are exposed to greater environmental dangers of death through accidental falls and fire.

The relatively high incidence of falls among the aged population is well illustrated in Figure 15. According to the Wolverhampton Survey, 35 per cent of all accidental falls were directly due to attacks of vertigo, while 31 per cent happened in the course of movement and seemed to be associated with a greater tendency of older people to trip (Sheldon, 1950). Apparently this is related to the increasing difficulty old people experience in coordination and in automatically recovering their posture. They also seem to have an increased need for more points of tactile support and kinesthetic stimulation, quite apart from the normally received visual information to maintain balance. In other words, old people need more environmental information than young people in order to maintain normal functions and activities and to avoid accidental disability at home.

"NATURAL" AND "SOCIAL" ONSET OF OLD AGE

Our survey of the special social and health problems of survival into old age would not be adequate if we did not discuss the severe sociopsychological impact of the time differential between the official and "natural" onset of old age. The evidence presented so far indicates that the majority of old people who live an ordinary home life, as a rule, cease being fully ambulant only after the age of 70 years. That is, the proportion of aged who are largely confined to the home rises unabated after age 70 years. Similarly, the chances for disabling or fatal accidents, and the chances for a chronic infirmity to make itself increasingly felt or to ripen into final disability, also increase significantly between the ages of 70–75 years.

Moreover, the longer old people live, the greater are the chances that severe added domestic and physical strains are placed on them because of extrinsic causes, such as having to care for minor children due to death or disability of their own children or relatives. Data obtained by Sheldon and his associates both indicate and confirm this and the other statements (Sheldon, 1950). He was also able to demonstrate that until the age of 70 years about 50 per cent of the women in his sample remained engaged in the sole domestic care of their household. Thereafter, a progressive decline in their proportional participation in domestic care took place until it reached a low of 4 per cent for those of 85 years (Fig. 16).

It appears that a woman keeps on going as long as she can by performing at least some parts of her total functions through sharing the domestic responsibility with others. The proportion of those engaged in housework by themselves alone begins to fall steadily after age 70 years. At the same time there occurs a rise in the proportion

of others who share with others in the same task Despite the increase of this proportion and despite the increased disability this usually implies, from 34 6 per cent at age 60 years to 51 per cent at age 80 years, women continue to have an important hand in homemaking (Fig 16)

The above body of data leads us to an inescapable conclusion Even though it is impossible to define precisely the time of onset of "natural" old age—a naturally infirm or decrepit old age that threatens an individual's independence—as a rule it does not make itself felt before the age of 70 years By the time an individual has reached 75 years, however, only the exceptional physical specimen can escape the biological and social consequences of his long survival This means that today's aging individual is presented with a crowning insult by the society he helped to uphold and build he is listed as old when he must retire at the age of 65 years while he can still look forward to at least 5 and often 10 more years of useful and fruitful activity

Needless to say the effect of this discontinuity or discrepancy between the "natural" and "social or actuarial onset of old age has a less striking effect on women at least initially As long as she remains thoroughly identified with the many and even complex habit patterns associated with maintaining a household finds solace by continuing to adhere to its many routines and experiences gratification from being needed even though on a reduced scale, retirement as such does not represent a violent change of habit to her

On the other hand man in today's industrial society does face such a necessary change of habit before he actually feels physically "played out" The prevailing fixed retirement pattern at age 65 years forces him to give up abruptly his identification with his occupation and its associated habit clusters By comparison with his wife, who if she is not a careerist can continue to perform important lifelong home functions and other community oriented activities, a man often cannot avoid feeling a vacuum of meaning and purpose

BOREDOM AND AGE

It is well known how often this feeling of boredom cannot be compensated for by the many socially contrived and recommended alternative work and leisure pursuits Many a retired male is likely to present a typical picture of the well known "withdrawal symptoms" when expected or asked to pursue a new activity He has lost the sense of continuity that the pursuit of his formerly legitimate lifework guaranteed He cannot be expected to whittle



Fig 16 —Proportional participation of women in domestic care of household in relation to age (After Sheldon 1950)

wooden spoons or weave baskets by the fire—activities that had meaning and still have for older peoples in peasant societies Our society has to face the twofold problem of trying to provide suitable incentives for the retired worker to engage in a practicable and useful activity *without* at the same time infringing on the rights of the younger generations by putting roadblocks in the way of their advancement No amount of improved social welfare legislation, family old age assistance and dependent care programs, and the like, can achieve this goal without the prior consent of the community, the family, friends, and neighbors They, above all, must try to find among themselves a place of meaning-

ful social participation for the prematurely retired aged

The majority of the older generation, nearly 95 per cent can continue to live as a part of the larger human group until death Only about 5 per cent may be classified as the true social or institutionalized isolates with no outside human resources even neighbors at their disposal It is regrettable however that more nearly 10 per cent of the entire aged population are faced with problems of health and social acceptance of such severity because of inadequate familial and communal planning for old age that many communities long before it should be necessary have to deal with an aged population that is in an advanced state of final bodily psychic and social incapacity

CHANGES IN PARTICIPATION IN COMMUNITY LIFE

It is understandable that aged people derive satisfactions from different life-activities than do younger persons The majority no longer have to cope with the problems and routines—and pleasures—of earning a living For these reasons we could expect them to avail themselves of the many added hours of leisure and to look for different opportunities of self expression and forms of recreation

Recreational participation —A 1935 survey of 5000 persons showed that people between the ages of 46 and 60 took part in about 42 per cent less activities than individuals aged 21–26 (National Recreation Association, 1935) A more recent study of 192 adult women and 176 adult men also reported that a constriction of interests in activities occurred at an older age (Kelly 1955) A study of leisure time activities among female elementary school teachers shows a continuous decline with age in the participation rate in nearly all physically active forms of recreation like dancing swimming, and skating At the same time a growing number of this sample began to fill their leisure time with rest and more hours of sleeping (Allard, 1939)

Pressey and Kuhlen (1957) note that the recreational habits of adults show 'a marked decrease in the sex social activities so prominent in the lives of the adolescents' but that "the data about the later years of life are not clear cut" The Cavan *study reported that the proportion* of persons over 60 years of age who scored a high degree' of participation progressively declined as the proportion of low scorers rose (Cavan *et al*, 1949) An unpublished study (Kuhlen, 1951), on the other hand revealed that increased leisure time in old age is associated with more leisure activities

Changes in interests —This discrepancy in findings on activities in late maturity appear to be related to the nature of the questions asked by the investigators, that is the interpretations of the results seem to turn partly upon the definition of what is an activity or an interest and what sample of the total aged population constituted the basis of the study We shall limit our discussion to changes in actual participation patterns, regardless of certain known changes with age in liking for or interest in various active and sedentary forms of participation

Suffice it to say that with increased age a decrease in liking for activities involving physical skill and daring , a decline of interest in linguistic activities involving writing [and a] greater dislike for changing activities has been reported (Pressey and Kuhlen 1957, p 394) This manifest change in interests with age has to be borne in mind when we evaluate the known changes in actual participation that occur with increased age If modern society wishes to learn how to enable its older citizens to develop a constructive way of life rather than merely a style of leisure or relative inactivity, it has to consider both this and the fact that the majority of people who pursue meaningful hobbies and the like in late maturity began cultivating

them in childhood, youth, and adulthood (Pressey and Kuhlen, 1957)

Activity and inactivity—In view of the above it is interesting to note that hobby activities decline consistently from late adolescence through middle adulthood Only after age 50 do hobby activities seem to increase until a person reaches the early seventies Thereafter, as could be expected with the diminution of sensory functions, they decrease again (Briggs, 1938) The Cavan findings are in substantial agreement with this (Cavan *et al*, 1949)

Another study of 381 old age pensioners, 70 years and over, revealed that about one-third of their daily activities had to do with housekeeping and the care of invalids or minor children and that games, hobbies, and intellectual pursuits, like reading, accounted for another third of the total activities listed Taking walks, calling on friends, clubwork, and church activities ranked next in importance However, it represented only 13 5 per cent of *all* the items mentioned Most significant of all nearly 10 per cent reported not doing much of anything in particular (Table 26)

The existence of a relatively high percentage of inactivity among elderly people has been corroborated by other studies (Fried, 1949) The implications of this fact have already been discussed in connection with the need to find more truly meaningful activities for retired people if they are to continue to feel that they are wanted by the human community

Viewing, listening, and reading—It would seem that with the prospect of an increased period of leisure made possible by the lengthening life span and earlier retirement from occupational life, many more older people can seek self expression in sedentary activities like reading watching television or movies, and listening to the radio A survey of age changes in these activities prior to the spread of television to almost every American home revealed that both movie attendance and average length of time spent at the cinema decrease with age For example, Table 27 shows that people 60 years and over spend only a little more than a third of the amount of time at movies than do people in the 20–29 age bracket

On the other hand, a constant increase in the amount of time spent on reading newspapers is evident In general, the average time spent reading a book decreases, while magazine reading habits show no appreciable change The figures indicate that people in their sixties spend somewhat less time than those in their twenties on mass

TABLE 26*

TYPE OF DAILY ACTIVITIES PARTICIPATED IN BY 381 PERSONS OVER 70 YEARS

Type of Daily Activity	Per Cent of 875 Items Mentioned
	32 9
	31 5
Walking, seeing and calling on friends, clubwork and churchwork	13 6
Resting, sitting in the sun, watching out of the window, "not much of anything"	0 6
Gardening, flowers, pets, livestock, chores	8 1
Employment, small jobs	4 3

* Source Morgan (1937) p 131

media activities but more than those in their forties As a rule, a high rate of participation of individual older persons in these leisure media reflects the degree of interest aroused and opportunity grasped in young adulthood and maintained through the normal work life

The advent and spread of television primarily changed radio listening patterns from a family habit to an individual activity Studies have shown that, although the total time spent on mass media increased nearly 1 5 hours, television set owners considerably reduced the amount of radio listening and magazine reading The decline in newspaper reading was only moderate

(Pressey and Kuhlen, 1957, p 397) The effect of these changes on the mass media recreational patterns of future generations of aged people may well be considerable Many informed persons have already noted the extent to which the present aged generation has come to use television as a constant companion and as a means of participating in "society on a passive, spectator basis

Space limitations do not permit us to spell out at length changes in the nature of interest in these various mass media of recreation and entertainment nor can we dwell on the changed psychological meanings of these activities among the aged population The important fact is that, among people who still work, these leisure activities are, in the main considered a peripheral activity For the retired individual however, they are too often the only important indexes of retaining membership in society

It has been noted that many of these activities, including hobbies, are no longer equally satisfying in retirement Not only do they remain peripheral to the majority of the working members of society in a symbolic sense but they also retain the same significance for many an old person and become a constant reminder of what he has lost upon retirement Moreover, most of these activities tend to isolate the individual from others as they do not require social participation in order to be enjoyed Thus the activities an older person can do in his increased leisure time should be of such a nature that he can—indeed, must—become more vitally engaged with others of varying ages Church and political activities are two forms of participation that beckon as answers to this problem of finding intensified forms of participation for the aged generation

TABLE 27*

CHANGE IN VIEWING LISTENING AND READING HABITS BY AGE GROUP

Mass Media	Age Group			
	20–29	40 49	60 and Over	Total
Books				
Per cent participation	27	17	18	21
Average time (minutes)	19	10	12	13
Newspapers				
Per cent participation	85	87	83	85
Average time (minutes)	31	39	44	35
Magazines				
Per cent participation	44	36	35	40
Average time (minutes)	22	19	20	19
Radio				
Per cent participation	74	74	75	74
Average time (minutes)	98	78	87	85
Movies				
Per cent participation	18	8	6	12
Average time (minutes)	24	12	9	18
Total time spent (minutes)	194	158	172	170

* Source Adapted from Link and Hopfitt (1946)

Church and political participation—Church and political activity is recognized as a time tested adaptation to the problem of finding a vital social role as an aging individual They are areas of social behavior where the old person can intensify his role as a citizen and elder through the exercise of leadership and moral counsel needed in solving critical events affecting the fabric of society as a whole

The aging individual who can find his place in these two social institutions is attuned to the prevailing values in an industrial society Today, perhaps more than ever, the direction and management of groups of people, the organization and integration of human and mechanical effort, is recognized as constituting a greater peak of power and talent, of ability, and influence than knowledge of how to manipulate or operate things and objects with skill and physical toil The individual who has the preparation for, the interest in, and the capacity to develop these modes of social participation is able to retain in a large measure a high level of symbolic societal rewards in his old age even if the tangible financial rewards decline

Church activity —Recent studies have shed some light on the relationship between church membership and personal adjustment in old age Moberg (1953) showed that church membership as such is not so significant to adjustment in old age as many other studies (Cavan *et al*, 1949, Schmidt, 1951) have reported He concludes that these studies found the existence of such a relationship largely ' because church membership is frequently related, however inconsistently, to religious activities and beliefs which are the true 'stuff' in religion that makes for personal adjustment" (Moberg 1953 p 210)

The difficulty of accurate measurement is pointed out by the fact that "many church members are members in name only and are concerned about church and its activities seldom except on such occasions as Easter and Christmas weddings and funerals Likewise, many non church members by their active participation in the church s program and adherence to the beliefs it encourages and fosters gain many of the personal and social benefits which flow from the church" (Moberg, 1953, p 211) It seems evident that the discovery of essential satisfactions from church and church related activities in the later years is more a function of whether a guiding interest had been developed and cultivated long before the increased amount of leisure time actually allowed a higher rate of participation as a bona fide church member

Studies of church attendance in the general population show that during the thirties a low point in religious observance is reached, partly because of the new demands of the dominant activity, one's occupation or homemaking, and the rearing of young children Thereafter, the trend is reversed until people in their sixties reach a level of participation in church and religious activities that is about equal to that during their teens (Fichter, 1952, Pressey and Kuhlen, 1957) When contrasted with the general decline with age of outdoor physical spectator and mass media activities the slowly increasing rate of church attendance with age could be interpreted as a net increase of religious interest and activity that is enough to reduce the mounting tendency in late adulthood to stay at home In view of the foregoing arguments, however, this interpretation must be accepted with reservation

Political activity —It is important to recognize that the social contribution of the voice of elders in political and civic affairs does not depend on the increasing number of elders or on more venerable longevity As long ago as 1000 B C, the problem of the power of the aged was present in society, and its existence was explained in terms of the accretion of wisdom and responsibility among the most talented few and long lived individuals Today we can still point to "councils of elders" at the national and local level Most "boards" in every town are manned by more people in late maturity than by the younger generation

Although the younger generations may rail at this evidence of their smaller voice in civic affairs and claim that the aged

munity and political affairs remains a real one All those elders who are board members, trustees, selectmen, and the like are

not newcomers to their respective roles They became involved in public affairs long before they entered late maturity The constantly growing proportion of older people in contemporary society has not ushered in a significant increase in the number and rate of participation in the existing councils of elders Instead the majority of elders find that the opportunity for new social roles past retirement is largely controlled by persons in their middle years impersonal governmental agencies and special commissions of experts who think and plan what is good in the way of activities and roles for them

Because of the widespread concern of local and national welfare agencies and the economic pressure groups of management and labor unions about what to do with the aged rather than what the aged generation can do for and in society there has been a growing tendency to see this segment of the population as a special group that needs protection or against which the working population has to protect itself We can cite predictions that by 1980 the balance of power in any election will be held by those over 60 or that the rapidly growing number of aged people will bring with it a movement to band together into a special interest and minority group and thereby usher in a new era of age-youth conflict as serious as that between capital and labor Pronouncements like these have been made by entrepreneurs and union leaders and by students of gerontology The existence of prejudice and stereotyping in employer and union rationalizations for discriminatory employment practices and the growing interest in and passage of special fair employment practice bills that include age in their coverage testify to the strength of negative majority feelings about the role of the aged quasi minority in civic, political and economic affairs (Barron 1953)

With this perspective in mind we can examine in some more detail the nature and extent of the civic and political participation of the aged Recent studies (Pressey and Kuhlen, 1957, pp 455–62) show that there exists a considerable lag in civic responsibility training, experience, and political awareness among the young at the time they leave public school as well as among a large segment of the adult population The negative effect this has on the creation of the necessary interest and motivation to participate in civic and governmental affairs in later years and especially in late maturity may well be considerable for a large number of aging individuals

A very detailed study by Kuhlen (1951) sheds much light on the voting habits and civic behavior of young and old male and female college graduates The findings recorded on Table 28 concerning participation in national politics show that up to around age 50 the proportion of men and women voting increases and then levels off until very late in life Until around the retirement age of 65, an increasing number of adults circulate petitions make political contributions or send a letter to a public official Thereafter letter writing continues high until the middle seventies and then drops off Contributions and petition circulating appear to drop after retirement

In the area of local politics (Table 29), interest in voting on local matters and in talking and reading about them increase until very late in life On the other hand participation in local activities like civic meetings and committee work increases only until the late forties and then decreases This decline is presumably less related to a diminished interest than to a reduced amount of energy available for such time-consuming activities (Pressey and Kuhlen 1957 p 462)

The above findings sound most encouraging insofar as they demonstrate the possibility of a continuous growth and expansion of civic responsibility in the later years It is a hopeful development that enables the aging individual to overcome a sense of social stagnation by replacing it with civic competence beyond the period of his active work life However, it is well to remember that the findings are based on a limited population that received more edu

cation and enjoyed greater socioeconomic advantages than the majority of the aged population today Nevertheless, it is to be hoped that with the continuing spread of higher education and an increasingly higher standard of living among the general population a higher proportion of the aged generation can and will avail themselves of the opportunities for participation in civic and political affairs

Old age and crime —We have said that a mounting number of people in society are beginning to regard the growing aged population as a minority or social pressure group with special problems of adaptation that, unless solved and channeled properly, could lead to increasingly disruptive crises and conflicts in the contemporary socioeconomic fabric We have also discussed other important obstacles, social, economic, and physical in nature, that the aged generation has to face if they are to continue to fill socially useful and meaningful roles in the community A consideration of these adaptational problems must include a discussion of criminal behavior as one of the many possible deviant responses of old people to the socioemotional frustrations and tensions associated with these problems

A variety of studies has shown that the

TABLE 28*

PERCENTAGE OF MARRIED MALE AND FEMALE COLLEGE GRADUATES OF VARIOUS AGES WHO PARTICIPATED IN SPECIFIED POLITICAL ACTIVITIES

Activity	Approximate Age					
	24 28	34 38	44 48	54 58	64 68†	74 90†
Discussed politics with friends						
Males	89	90	89	88	90	83
Females	85	87	75	86	76	
Listened at least once a month to political speeches discussions						
Males	73	71	76	84	82	79
Females	77	68	73	81	86	
Voted in last primary or local election						
Males	55	72	82	87	82	83
Females	51	68	83	90	81	
Read one or more books about politics						
Males	25	18	10	17	15	28
Females	9	16	4	15	17	
Signed a petition for or against some legislation						
Males	16	33	29	27	24	17
Females	24	31	40	27	43	
Sent letter or telegram to public official						
Males	14	26	28	29	31	24
Females	12	15	29	29	31	
Contributed money to some political cause						
Males	5	17	24	32	26	17
Females	12	15	19	27	21	
No of cases						
Males	45	161	108	193	90	32
Females	86	76	53	60	42	

* Source Kuhlen (1951) Pressey and Kuhlan (1957) p 460

† Age was estimated from year of college graduation assuming graduation at age 22 The final age group for females is actually made up of the graduating classes of 1879–1905 There were more male respondents at the upper ages permitting the carrying of the age breakdown to a later age for males To condense the table figures for ages 29 33 39–43 etc have been omitted as have also certain responses

total amount of crime declines with age and that trendwise there is no indication that an increase of the proportion of the aged in the population will increase the amount of crime According to Moberg (1953), the aged in the United States, England, and Sweden "have consistently committed only a very small proportion of the total amount of crimes which resulted in apprehension and conviction" Pollack (1941), studying United States arrest rates during the years 1935–37, found that the crime incidence for people 50 years and over was lower for all crime categories than the incidence rate for people under 30

East (1944), who examined the annual reports of the prison commissioners in England for the ten year period 1929–38, showed that people aged 60 and over committed only 2 03 per cent of all acquisitive offenses, 6 48 per cent of all aggressive offenses, and 8 04 per cent of all sex crimes that led to imprisonment Table 30 clearly shows the extent of decline with age in the offense rate per 100,000 population in the United States Briefly stated, people of all ages commit all types of crimes, but younger persons commit more in each category

Pressey and Kuhlen (1957) note that it is difficult to obtain exact estimates on ei

TABLE 29*

PERCENTAGE OF MARRIED MALE AND FEMALE COLLEGE GRADUATES OF VARIOUS AGES WHO PARTICIPATED IN SPECIFIED CIVIC ACTIVITIES

Activity	Approximate Age					
	24 28	34 38	44 48	54 58	64 68†	74 90†
Followed local events in newspaper						
Male	76	90	97	94	96	87
Female	82	97	98	97	93	
Talked with neighbors regarding better neighborhood						
Male	39	53	55	62	66	43
Female	52	62	67	57	58	
Attended meetings of civic groups						
Male	35	55	60	56	42	33
Female	35	50	73	60	63	
Contact with local official about a a civic problem						
Male	26	36	39	44	42	23
Female	18	35	27	23	19	
On a volunteer committee for community service						
Male	15	39	46	43	30	20
Female	28	41	63	53	30	
Collected money or carried petition for local cause						
Male	15	25	32	34	21	17
Female	20	30	43	43	19	
Helped a group such as the Boy Scouts						
Male	17	28	34	24	22	20
Female	21	27	35	30	19	
No of cases						
Male	45	161	108	193	90	32
Female	86	76	53	60	42	

[illegible] have been omitted, as have also certain responses

ther the nature or the extent of crime in old age They point to problems of crime detec tion, of limitations of legal terminology, and of legal practices which often permit an offender "to plead guilty to lesser charges, [or] be given suspended sen tences or fail to be committed' (Pressey and Kuhlen, 1957, p 475) Since studies in other countries confirm findings for the United States, we may, however, have rea sonable confidence that the decline of crime rates with age is an established fact drunkenness and gambling arrests falls be- tween the early and late thirties, respec tively The percentage distribution of of- fenses on Table 30 clearly shows that drunkenness, embezzlement, fraud, and sex offenses tend to predominate in the older age categories

The higher rates of white collar crime and of sex offenses, especially "other sex offenses," which include the more indirect attempts at sexual gratification, appear to reflect the known changes in strength and energy level, the decline in recklessness, and changes in personal and social relations with increased age (Moberg, 1953) Actu ally, if the rate of sex offenses is computed differently, the rate for 'other sex offenses" reaches its highest point in the 40–44 age group and its lowest ebb in persons 65 years and over (Pressey and Kuhlen, 1957)

TABLE 30*

PERCENTAGE DISTRIBUTION OF CERTAIN OFFENSES WITHIN AGE GROUPS MALE FELONY PRISONERS RECEIVED FROM STATE AND FEDERAL COURTS 1946

Type of Offense†	Median Age	15 19	25 29	35 39	45 54	56 and Over
Murder	30 5	1 76	3 59	4 84	5 05	7 61
Robbery	24 0	11 58	10 50	5 95	3 15	1 09
Aggravated assault	28 7	3 78	6 86	7 82	6 72	11 41
Burglary	23 9	30 52	16 80	13 85	10 57	6 79
Automobile theft	22 7	16 98	9 10	3 91	1 45	0 27
Embezzlement and fraud	33 8	0 74	2 57	3 81	5 83	7 61
Forgery	29 3	3 13	8 16	8 22	9 68	5 98
Rape	26 6	2 93	4 88	4 09	4 02	6 25
Other sex offenses	37 1	0 79	1 77	3 10	6 31	15 49
Violating drug laws	34 5	0 46	2 17	3 75	5 58	2 45
Non support or neglect	33 8	0 08	1 58	2 70	2 12	
Violating liquor laws	36 4	0 40	2 81	5 99	8 62	11 41
Total	26 6	100 02	100 04	100 01	99 99	99 99
Rate per 100 000 population		148 50	176 34	99 01	43 42	7 58
No (excludes 34 under age 15)		8748	9830	4962	3584	368

* Source Pressey and Kuhlen (1957) p 476 Data computed from U S Bureau of the Census *Prisoners in State and Federal Prisons and Reformatories 1946* (Washington D C Government Printing Office 1948) Table 33 p 46 and United Nations *Demographic Yearbook 1948* (Lake Success N Y United Nations 1949)

† Certain offenses have not been included in this condensed table because they are relatively rare at every age (as carrying and possessing weapons) or involve trends better indicated by other offenses (so aggravated assault and murder more clearly indicate age trends in crimes of violence than manslaughter which was omitted) Median age and totals are for all felonies in the original tables however The highest crime rate occurs in the age group 20–24 (rate of 245 27 per 100 000) according to this analysis

Of more interest to students of the be havior of the aged is the fact that ' there is a much greater probability of young per sons being arrested for the most serious felonies" (Clinard, 1957, p 198) Table 30 reveals that persons who were apprehended for theft, burglary, larceny, and robbery have a median age of under 25 On the other hand, the median age for arrests for embezzlement and fraud and receiving stolen property and the median age for

It is perhaps more significant from a so cioeconomic point of view that white-collar crime is relatively high among the aged

Moreover the very high proportion of first offenders (Moberg, 1953) and a minimum of confirmed or hardened criminals in the aged population must be considered when we interpret the meaning of old age crime These facts would seem to indicate that the pattern of crime in old age is related as much to increased physical obsolescence as to changes in social and economic status and particularly to the reduced opportunities for continuing emotionally gratifying interpersonal activities

Drinking patterns and alcoholism —Before arriving at an answer about whether alcoholism is a particularly serious social problem in the aged population it is well to remember that in the United States about two thirds of the adult population over 21 years old drink some type of alcoholic beverage during any given year Maxwell (1952) reported in his study of drinking behavior in the state of Washington that 63 per cent of the total population, and more men (76 per cent) than women (51 per cent) consumed alcoholic beverages In a national survey Riley and Marden (1947) also found a similar widespread use of alcohol (65 per cent) and that approximately one in two women as against three in four men drink spirits beer or wine

the United States The frequency of drinking varies with sex in the national survey mentioned above about 8 per cent of the females and 27 per cent of the males drank three or more times a week Only 17 per cent of the total group were classifiable as regular drinkers of this type The state of Washington study only reported one in ten persons as regular drinkers or three out of a hundred women and one in five men

Studies of rural urban and geographical differences in the proportion of the population who drink show that relatively less drinking is done in rural than in urban and industrial centers and that the ratio of abstainers to drinkers seems to correspond to certain known geographical and economic regions of the United States where farming or industrial activities predominate and where a higher or lower population density exists (American Institute of Public Opinion 1948)

It is most difficult to find a single expla

appears to decline with increasing age and that educational, occupational, religious, and ethnic factors do play a role in furthering or limiting the development of excessive drinking habits that may lead to alcoholism nothing very specific can be said about the prevalence and incidence of severe alcoholic reactions among the aged Riley and Marden (1947) reported that almost three quarters of people between the ages of 21 and 29 drink The percentage of people between age 30 and 49 who drink drops to two thirds and reaches only one half for people 50 years and over The American Institute of Public Opinion (1948) revealed that people with more than a high school education (70 per cent of this group) drink more than those with less education (62 per cent)

According to Jellinek (1946) and others (Fleming and Tillotson 1937, 1939, Amark 1951), alcoholism is more of a problem for people under 45 than for the aged generation They report that for the majority of alcoholics the alcoholic process, from the point of commencement of abuse, begins in their middle twenties and that, on the average, this process culminates in the lowest ebb of alcohol addiction, requiring some form of treatment, at about 40 years of age

Studies of groups of isolated individuals, with particular reference to homeless men, whether itinerant worker, tramp, or hobo, show that although many are or become excessive drinkers, by no means all are or turn into severe and chronic alcoholics (Straus 1946 1948, Straus and McCarthy, 1951) For the great majority of these individuals drinking is a part of the routine of living, only 10 per cent of this group

drink to the limit and alone every time they can

One study of 444 such persons (Straus and McCarthy 1951) reported the median age as 51 3 and 43 6 years for the white and Negro complement respectively This does not indicate however that age alone is the important factor in their condition A more outstanding characteristic is their lack of marital ties and low employment status Over one half never married and one third were either separated or divorced and only 12 per cent were widowed Two thirds of the studied population had always been unskilled workers and of the remainder nearly all had never been more than marginal or part time workers

It is clear therefore that these studies are dealing with a deviant social group rather than a group of persons who became addicted to alcohol because of the trials of growing old In other words in the light of our present though by no means adequate data on drinking patterns and alcoholism excessive drinking habits and alcoholism as such do not constitute a major social problem in our aged population

Drug addiction —Substantially the same conclusion can be made regarding drug addiction in the aged population According to United States government statistics (U S Treasury Department Bureau of Narcotics 1956) drug addiction is primarily a problem among younger age groups and consumption of drugs has been increasing in this population Arrest statistics for persons under 25 years of age January June 1951 *reached 48 8 per cent in* contrast to 31 4 per cent for the same age group during the same period in 1941 In 1955 the majority of those arrested for violations of federal narcotic laws were 30 years or under Persons aged 21 30 comprised 54 2 per cent of the total arrest and those under 21 years of age accounted for 9 per cent

Although the extant statistics on narcotics users have similar shortcomings as the data on crime rates a study of 1036 committed and voluntary drug addicts at the USPHS Hospital in Lexington Kentucky tends to confirm the contention that drug addiction is not at present a serious problem in the aged population (Pescor 1938) Table 31 tells us at a glance that about two thirds of the individuals who developed an addiction to narcotics did so before they reached 30 years of age Nearly two fifths were less than 25 years old when they became addicted In contrast only one half of 1 per cent of those 60 and over showed an onset of addiction at that age Of equal sociological significance is the fact revealed in another study (Dai 1937) that drug addicts generally attribute their addiction to the personal influence of other addicts and to having become gradually involved

TABLE 31*

AGE AT BEGINNING OF ADDICTION OF 1036 HOSPITALIZED PATIENTS

Age at Onset of Addiction	Per Cent
19 or under	16 5
20 24	28 1
25–29	25 1
30–34	14 2
35 39	6 9
40–44	5 4
45–49	1 7
50–54	0 8
55 59	0 5
60 or over	0 5
No record	0 3
Total	100 00

*Source Pescor (1938 p 24

the author that specifically deal with the problem of drug addiction in old age we conclude that the over all national statistics and the hospital data presented may be taken as presumptive evidence that narcotics addiction is a relatively minor issue for our aged population In this connection it would be of interest to know to what extent the rising medical and non medical use of pain killing drugs and tranquilizers has affected the attitudes about habit forming

drugs including narcotics among older persons in general as well as their effect on the rate of drug consumption among those aged individuals who are facing or under going a prolonged period of partial and ter minal physical incapacity

VI An Overview

This chapter was not intended as an ex haustive statement of all the significant as pects of the socioeconomic background of today s aging citizen On the other hand we believe it to be an up to date synoptic discussion of some of the more important socioenvironmental problems and changes that confront our aged generation A brief summary will enable the reader to judge for himself as to the nature and extent of these changes

If we compare the socioeconomic context of the aged individual today with that of his grandfather we can identify significant changes in four major areas all of which have been affected to a considerable degree by his increased longevity In the more typ ical rural society where the majority of our great grandfathers grew up the economic status and pattern of work participation of the older person was largely geared to be ing a self employed owner and manager of a farm or small business He retired grad ually if at all and primarily at his own vo lition so that as a rule he managed to remain economically independent in old age

In today s primarily urban and indus trialized society the majority of older per sons have worked as employees in a cor porate enterprise under some form of or ganizational supervision and under a union contract. Retirement is generally not based on a flexible system of being able to shift from a physically demanding to a less tax ing occupation It usually rests on a fixed actuarial age limit which both labor and management consider as binding Econom ic security in old age is now less based on accumulated individual savings and a post ponement of occupational inactivity than on a system of government employer and union sponsored social security

At the same time important changes have taken place in the family life cycle In this area of change we can point to the decline in family size and to an increase in occupational and geographical mobility which brought with it the decreasing op portunity and growing inability of single or married children to care for their aging par ents This has also been accompanied by a value shift from familial responsibility for the aged individual toward public responsi bility for the aged population Together with the decline of the large and extended family as an insurance against old age the necessity to be the sole economic support of the family has been gradually reduced and the opportunities to organize the family along economic as well as social lines by training and supervising one s offspring have been diminished

In addition certain changes in social and civic participation habits have taken place In part they are related to the added pe riod of leisure time due to increased lon gevity They are also attributable to more general social changes in the recreational and entertainment habits of the commu nity There has occurred a noticeable shift away from basically home centered activi ties those involving neighborhood groups or the out of doors to a variety of recrea tional patterns that put a premium on spec tator or audience functions and which usu ally are enjoyed by aggregates of people The opportunities for continued active par ticipation in civic and political affairs as a way of maintaining one s social status in old age have also been more difficult to find This change is associated with the in creasing number and longevity of the aged certain subtle changes in the system of rep resentational government the rapid growth of organization living and the spread ng re liance on state and national agencies to solve community and neighborhood prob lems

Lastly we must not forget that the tri umphs of modern medicine played a vital

role in ushering in an era where premature occupational obsolescence must be contended with by a growing number of often insufficiently prepared but longer living individuals Moreover, some of the related sociomedical problems faced by today's aged people, especially the likely prospect of prolonged physical debility and terminal incapacity, constitute unique crises of adaptation that did not have much meaning for the aged at the turn of the century

Contemporary society faces the task of finding for and with its aged generation new ways to postpone or eliminate the growing problem of premature social and occupational obsolescence and to contract the lengthening period of terminal total incapacity

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XI

The Relation of Human Health to Age, Place, and Time

HARDIN B. JONES

I INTRODUCTION

Definition "The term *aging process*, as applied to living organisms, is the genetically determined, progressive, and essentially irreversible diminution with the passage of time of the ability of an organism or of one of its parts to adapt to its environment, manifested as diminution of its capacity to withstand the stresses to which it is subjected, and culminating in the death of the organism" (G H Hunt, personal communication)

This chapter discusses evidence that death risk is a gross measure of health and aging, that the total death risk may be analyzed into meaningful factors for abstract subpopulations in order to study the effects of specific environmental variations, and that variations in these measures with age, place, and time support the concept that health and aging are modified by environmental circumstances

Health may be evaluated in terms of degree of change in properties, such as various mental characteristics and many physiologic functions, that are known to depend upon age Some of these changes have been measured with fair accuracy, suggesting that a specific physiologic description of aging may be attainable In spite of such examples, however, we are far from realization of the goal of a functional understanding of aging Indeed, even in those areas where some degree of understanding has been developed, the samples studied have been too small to permit really satisfying generalization of the conclusions reached, and we must rely upon other sources having sufficiently large numbers to establish, with statistical reliability, the broad features of individual variation in health with respect to age time, and geography In the present state of knowledge the principal measure of relative aging or health is the difference, with respect to the probability of death, between the populations undergoing comparison

Census records and vital statistics [illegible] deaths and causes of death) give [illegible] vidual countries (United Nations, [illegible]) whose populations have been variously divided into subgroups, have been analyzed from this viewpoint Rough estimations of health, as gauged by death rate, age at death, and other life table measures, are available on about 1 5 billion people in these countries and in some instances can be traced back for 300 years

Death rate is an important descriptive measure because of the unique correspondence between death rate and age during adult life for a given population The age of a group within a defined population can be estimated from its death rate, and the rather extraordinary variations in death rate between sample populations at corre-

sponding chronologic ages may be interpreted as differences in relative health or relative physiologic age of the samples There can be little doubt that the Scandinavian countries, Denmark, Norway and Sweden, have achieved a relative health far superior to that of most other parts of the world, whether measured by risk of death from all causes or by risk of death from almost any single cause

Loeb and Northrup (1917) Brody (1923), Pearl (1928), and Jones (1956*b*) have all presented somewhat similar arguments that death rate is an effective measure of relative physiologic age It is impressive to use the graphic method in presenting this argument If we let the ordinate represent death risk in terms of deaths per unit of population per stated fraction of life span, with age in terms of fraction of life span as the abscissa then a single curve approximately describes the biology of aging in humans, horses dogs rats, mice, and flies (Fig 1) A corollary of this relation is the fact that the relative annual increase in the death rate as a consequence of aging is a constant fraction which depends upon the species concerned This property of constancy of the relative increase in death risk with age is perhaps the most intriguing mystery about aging and it provides as well, one of the principal tools by which we can examine the process of aging The property of constant relative increase in death risk is often referred to as the "force of mortality" The force of mortality, measured in terms of either the rate constant or the equivalent 'doubling time" for death rates varies with species, but, quite remarkably, it is usually the same under a variety of circumstances for a given species

Not only does the death rate from all causes for a given population increase at a constant relative rate with age but also the rate for almost any selected cause of death increases at about the same pace Many of these causes—cancer vascular disease, diabetes—are linked to the quality of internal metabolism In adult human populations these causes frequently account for 60–80 per cent of the total deaths It is reasonable to assume that these deaths are the result of aging in the sense that decay of functional vigor somehow underlies the onset of these functional failures Additionally the susceptibility to death from an infectious disease increases with age, and even the number of deaths attributed to accident shows this trend Possibly, in the case of accident, it is the decrease in reparative processes and in the chance of survival following a given degree of accidental injury that is responsible for the increased mortality with aging In any event, whether the initiating circumstances are internal or external, age on the average determines the probability of survival, and the death rate by age can be used as a measure of relative functional vigor or physiologic age of a defined population for the purpose of comparison with other populations

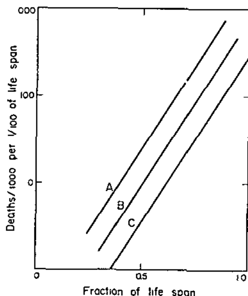


FIG 1 —The force of mortality Similar curves apply to various species, the corresponding life spans are approximately man 100 years, mouse 1000 days fly 1000 hours Curves *A* *B* and *C* represent successively better states whether with respect to genetic factors overt disease or environment

II Do Individual Differences in Aging Exist?

At this point it is convenient to discuss the question whether true differences in aging occur This is a many faceted problem, and all perspectives from which it is viewed do not necessarily lead to the same conclusion For example a reasonable case can be made for the argument that aging is invariant

1 Despite some exceptions, the force of mortality is roughly constant under a variety of circumstances

2 Risks of cancer death at specified ages (age specific cancer mortality) are much more nearly constant from place to place and time to time than the risks of any other cause of death, possibly implying that aging as measured by cancer incidence may be more nearly a common characteristic of mankind than the variation in other causes or in the total death risk would lead one to believe (The argument is weakened by the fact that differences in cancer risk between populations selected by time or place nevertheless are present)

3 Where differences in age-specific death rate are observed, much of the variability might be attributed to genetic differences, inconsistencies in the methods of collecting vital data among the various population registries, and the local variation in intensity of action of specific causes (Of course, local variation in the intensity of specific causes may be interpreted as evidence of individual differences in aging, and, as will be explained, there are methods for estimating aging trends in causes of death independently of some of the bias incurred by the varied conventions of classification within the subpopulations)

It is the over all contention of this chapter, however, that differences in relative physiologic age and health at given chronologic ages do exist and are the result of specific factors that permit some modification of aging

III Infectious Disease, Life Span, and Aging

It is an established fact that mortality from infectious diseases has almost disappeared over the past century and that much of this change has occurred during the last 50 years It is tempting at this point to divert the discussion into a consideration of how and why these diseases have diminished their toll It is obvious that many specific remedies have been applied against these infections in terms of both individual care and preventive public health measures Yet, while mortality from most of these diseases shows a consistent trend downward, with greater relative gain in more recent times, there has nevertheless been little decisive concurrence of major discoveries with declines in the total mortality The effect of antibiotics, it is true, is seen dramatically in the decline in deaths from tuberculosis and pneumonia from 1940 to 1950, but the downward drift in death rates from all causes for this decade is consistent with the expectancy extrapolated from the trend of the last 50–100 years Consequently, we may suppose that the gains in relative health are attributable to a large number of factors probably acting continuously over this period It is possible that the decline in infectious disease may have had its origin in improvements in living conditions and nutrition—trends that began to accelerate in the late nineteenth century If this be the explanation of the trend, the specific contributions of

tem of resisting disease As will be discussed later, agents such as vaccination and antibiotics may have a more pronounced beneficial effect when viewed over the whole life span than their specific, immediate action in producing a decline of mortality from an acute infectious event

The most obvious factor responsible for the increase of life expectancy recently is

the decline of mortality associated with the infectious and childhood diseases Prior to 1900, tuberculosis was the leading cause of death at nearly all ages, the tuberculosis death rate has since fallen to 10–15 per cent of its former value and is still declining rapidly Scarlet fever, whooping cough, and diphtheria have nearly vanished as measurable causes of death With the possibility of suppression of streptococcal infection, rheumatic fever, too, may disappear The sum of all these benefits has been that humans, especially children, have recently been exposed to less total disease trauma and risk of death so that a much larger proportion of infants survive and develop into adults This fact is largely responsible for the shift in mean life expectancy at birth in Western countries from about 30–35 years in 1900 to about 68–75 years today The situation is analogous to that of two individuals who start out with equal fortunes not subject to replenishment The one buying fewer items and spending less per item (characteristics usually common to both economics and health) will have more of his fortune remaining at any time indeed, the difference between the thrifty individual and the spendthrift may be very great

In the adult ages, deaths from these infectious processes diminish, perhaps because of the increased prevalence of naturally acquired immunity to these diseases and the likelihood that those of lesser resistance have already disappeared from the population to a large extent Consequently, if we examine either death rate or life-expectancy, it appears that there is less apparent change per year of age for adults than for very young children with regard to life table death risk It is easily demonstrated, also, that the death rates and life-expectancies for older adults at any selected age show less range of variation in a compared sequence of calendar years In fact the older the age selected for the comparison the less the apparent variation Generalization from this important fact, however, leads to extremely divergent opinion concerning the process of aging

The generalization usually drawn from the fact that environmentally caused gains in life expectancy or death rate in a given population decrease with age is that basic factors of aging are invariant and that internal aging eventually takes control, in

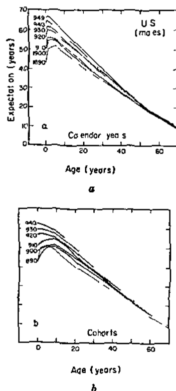


FIG 2—Life-expectancy of United States males (*a*) by calendar years 1890–1949 and (*b*) by cohorts 1890–1940

spite of gains related to reduction in environmental hazard This aspect is apparent in Figures *2a*, *3a*, and 4, in which it may be observed that the lines expressing either life-expectancy or death risk by age converge toward the older ages so that, at 70, 80, or 90, there remains little of the apparent relative gain noted in earlier years

Quite a different generalization may be reached from this same information if we employ an analysis of aging based on con-

tinuity of disease experience as a controlling factor in determining the morbidity and mortality of a population This is a more effective way of separating the two distinct phenomena involved the effects of time on the aging process and on the health characteristics of the environment In Figures 2*a*, 3*a*, and 5 comparisons are made between groups that have attained the stated ages in designated calendar years For groups of different ages their

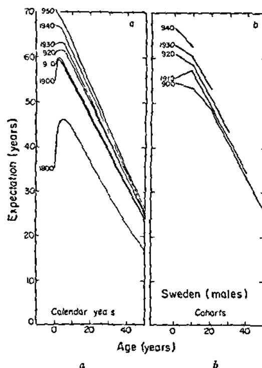


FIG 3—Life expectancy of Swedish males (*a*) by calendar years 1800–1950 and (*b*) by cohorts 1900–1940

early years were spent in different environments Average disease experience has changed drastically in the last century Those who are 60, for example, lived their childhood and developmental life over 40 years ago, when control of childhood diseases was much less effective Since there is evidence that adult health is related to disease experience in the developmental period, it is pertinent to analyze the characteristics of aging, not by comparing groups that attain different ages at a given calendar time, but rather by comparing death risk or life expectancy by age for individuals born at the same time Since such a group moves through the years as a unit or cohort, this method is termed "cohort analysis"

Cohort analyses are shown in Figures 2*b*, 3*b*, and 5 Regardless of the samples selected, this method seems to yield parallel lines for the various groups, thus indicating constancy of the force of mortality The lines distinctly do not converge as in the analysis by calendar time We can conclude, therefore, that characteristics of health in a population sample are determined early in life and follow a course of deterioration at a rate characteristic of the human species These generalizations will be extended further in evaluating a number of factors influencing the developmental period and in considering a theory of aging

IV Genetic and Environmental Factors in Aging

The same diagrammatic form describing death risk change with age is suited to comparisons of genetic or environmental factors with respect to aging Figure 1 presents a somewhat simplified example of death rates modified by genetic selection Those lines selected for cancer other disease tendency or shorter life span display a higher risk of death at any age than more vigorous lines Identical genetic lines maintained under different environments may become as distinct as different genetic lines raised under the same environmental conditions and similarly show differences of death rate Without exception, less adequate environments are associated with elevation of the risk of death throughout the life span

Using the concept that physiologic age is related to death rate, we can say that the strains described as differing in genotype or in environment during development reach equivalent physiologic ages at different times, and this displacement between pairs of populations is constant regardless of age This generalization establishes a corre

spondence between physiologic age and genetic or environmental variations The remarkable feature about the interplay of most environmental differences during the postdevelopment period is the fact that death rate or life expectancy alone is changed, not the rate of increase of death rate with age (the force of mortality) Since the force of mortality remains unchanged in differing environmental states, most environmental factors during this period of life must alter the basic risk by a fixed factor dependent upon the nature of the circumstance The basic features of aging appear not to be affected, or at least not affected noticeably (this may be a qualification of importance here, because the sensitivity of measurement of force of mortality is considerably less than other life table characteristics) It has been shown, however, that a continuing morbidity inducing agent such as chronic radiation exposure alters the force of mortality throughout the period in which it is applied (Jones, 1957)

An elevated death risk acquired through genetic constitution, trauma, or radiation injury remains elevated, increasing accord

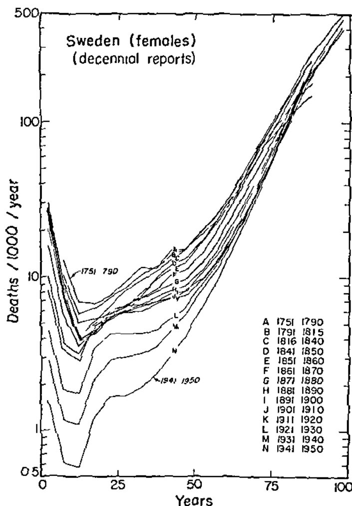


FIG 4 —Death rates of Swedish females by calendar years 1751–1950

ing to the usual exponential character of the force of mortality It would be proper to conclude, therefore, that these effects are irreversible and that their consequences are equivalent to those of the passage of time In this way, a correspondence can be shown between aging time genetic constitution, and some states of morbidity

V Acute and Long Term Effects of Illness

In radiation exposure both immediate mortality (associated with radiation sickness) and long term effects on the death rate simulating aging, have been shown to depend upon the degree of exposure Acute radiation exposure effects can be modified by change of the rate at which a given total dose is administered and by applications of antibiotics, reticuloendothelial transplants, shielding of spleen or bone marrow, etc, without influencing the long term aging effect of irradiation It appears then, that acute effect per se is not the feature determining aging, rather, aging results from some other characteristic feature of radiation exposure that is unaffected by the above remedies for acute

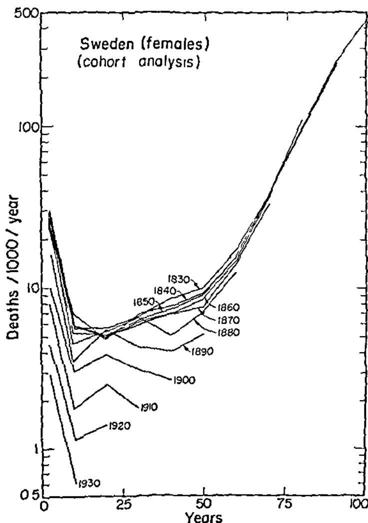


Fig 5 —Death rates of Swedish females by cohorts, 1830–1930

exposure In acute illness, too, there is likely to be a narrow margin at times between survival and death, where an extra increment of morbidity may tip the scales toward death and yet not appreciably worsen the extent of recovery if recovery, indeed, ensues A remarkable example of this system in humans can be drawn from the vital statistics of prisoners of war

VI Health and Mortality of Prisoners of War

It is quite comforting to know that prisoners of war in most circumstances of confinement have not shown an excessive mortality following release from internment Prisoners held by Japan in the Pacific area did show excessive mortality during their imprisonment and, in the one instance of reported follow up for six years thereafter, have persisted in showing an elevated death risk equivalent to aging

In Santo Tomas Internment Camp and related prisons in the Philippines, 435 deaths in approximately 6400 internees were observed during a 3 4 year period (January 4, 1942—June 4 1945) (Pearson, 1946) The excess mortality is greater in males and is equally distributed over the range of ages, standardized mortality ratios (SMR) of 236 for males and 130 for females are obtained by applying estimates to the sample vital statistics reported by Pearson as of 1945 Subsequent follow up of these people is not reported

A roughly parallel situation is reported by Bergman (1948) with respect to mortality of internees in Java in 1944 and 1945 The age distributed mortalities are presented in Figure 6 Here is the accounting of 10 350 male civilians, aged from 10 to 85 years, followed from February, 1944, until August 1945, or prior death (744 died) They are shown in comparison with the corresponding vital statistics of the male Australian population for the period 1944–45 A remarkable feature of the effect of environment on age distributed mortality can be appreciated in this diagram Mortality for each age is increased by the same proportion regardless of age Equivalent elevations of death risks, affecting all ages, are observed repeatedly under environmental conditions of various kinds (Figs 6 and 8) As the environment deteriorates further—or, more likely, as the internees deteriorate through protracted exposure to conditions of infection and

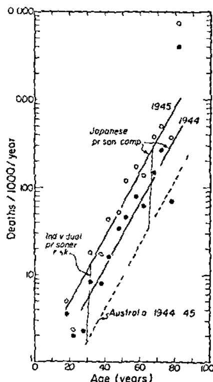


Fig 6.—Death rates of Australian prisoners of war 1944–45

starvation—the death risk increases, so that the rate during 1945 is approximately double that registered for 1944 In this instance, too the stress affects the death risk to the same relative extent at all ages Since the risk is proportionally elevated at all ages, its intensity at older ages makes survival rather improbable, even though young adults may weather the ordeal For example, at age 73, death risk is about 50 per cent per year It is not surprising, therefore, that the obvious condition for

survival in these internments involved age The younger individuals fared far better than those of advanced or even middle age

The lines representing the average age-distributed mortality in Figure 6 do not express the situation affecting the individual each individual's risk is changing in the way illustrated by the two examples drawn upon the figure, corresponding to ages 30 and 65 at internment These individual risks increase sharply, the death rate increases by a factor of 3 during the first year of internment and is nearly eight times its initial value by the end of the second year This relation implies that had the imprisonment extended another year under similar conditions the risk of dying for the entire population over age 40 would have exceeded 100 chances per 1000, essentially eliminating all older individuals These two illustrative examples portray a change in the force of mortality during exposure At the same time they reflect the acute period of starvation and disease to which the survivors were also exposed The inference follows that these individuals may have incurred some permanent decrease of health, even though liberation and subsequent care led to a recovery of the major attributes of health Bergman writes "The process itself [decline of health with internment] is fortunately not irreversible Every physician with experience among ex prisoners knows that many of them made remarkable recoveries They regained their physical ability and mental fitness to an astonishing degree most of them are at work again although they remain more grey and wrinkled than fits their real age" (1948 pp 16–17)

A postinternment follow up is available for United States armed forces personnel (Table 1) It is only the group interned by Japan, largely from the Philippines, that is materially affected, according to the 6 year follow up reported While follow up to the present time would be more meaningful than just the 6 year study presently available, it appears likely that such internees have, on the average, experienced some 4–8 years of aging as a result of this experience and nearly the same reduction of life expectancy if these risks continue Whether the causes of this situation are true injuries persisting from the morbidity experiences incurred during internment or the composite effect of various residual states of chronic infection is difficult to say It is remarkable that, under the circumstances of multiple acute afflictions in each person during this period, recovery left so little effect upon average health

Starvation and duress of less severity afflicted the entire population of the Netherlands during 1945 Figure 7 illustrates the fact that these people experienced the same sort of relative intensification of death risk at all ages as in the case of prisoners of war, but, even in the next year, the residual effect of the experience was imperceptible The somewhat disproportionately greater increase in death rate at ages 18–50 may reflect the additional physical hardship imposed on able bodied men during this catastrophe Starvation sufficient to increase the average mortality of a population by 70 per cent, acting for less than a 1 year period, appears to impart no lasting effect

VII A Theory of Aging

The force of mortality, nearly constant from postadolescence to senescence, presents a powerful argument for the concept of a continuous decay of vitality as expressed by Loeb and Northrup (1917) and others (Brody, 1923, Pearl, 1928, Jones, 1956*b*) The process may also be regarded as a growth of impairments of various kinds, from this viewpoint, it would appear that the chance of incurring additional impairment at any time is proportional to the sum of past accumulations of impairment (Jones 1956*b*) As stated previously, this theory would hold that death rate is a measure of physiologic age and also of internal impairment

The theory holds that most kinds of

TABLE 1*

Mortality of Released Prisoners of War

White males of United States Army and Air Force, aged 20 or more when liberated, followed for ensuing 6 years "Expected" mortality data based on Life Table for United States White Males, 1949, except for analysis by cause of death, latter based on average of *Vital Statistics of the United States* for 1946 and 1949

PRISONERS HELD BY JAPAN (GROUP PWJ)

Age	No	Deaths		
		Observed	Expected	SMR†
20–24	444	14	4 6	300
25–29	917	25	10 2	250
30–34	280	9	4 3	210
35–39	113	3	2 7	110
40 54	76	7	4 3	160
Total	1830	58	26 1	222
Subtotal, 20–39		51	21 8	234

Years Follow up	Observed Deaths	Death Rates		
		Observed	Expected	SMR†
0–1	21	11 48	2 11	544
1–2	9	4 92	2 21	223
2–3	9	4 92	2 28	216
3–4	3	1 64	2 40	68
4–5	5	2 74	2 53	108
5 6	11	6 01	2 70	223
Total	58	31 71	14 23	222

*Source Cohen and Cooper (1954)

PRISONERS HELD IN EUROPE (GROUP PWE)

Age	No	Deaths			SMR Ratio, PWJ/PWE
		Observed	Expected	SMR†	
20–24	904	7	9 3	80	3 8
25–29	561	6	6 3	100	2 5
30 34	188	2	2 9	70	3 0
35 39	65	1	1 5	70	1 6
40–44	4	–	0 1	–	–
Total	1722	16	20 1	80	2 78
Subtotal, 20–39		16	20 0	80	2 93

Years Follow up	Observed Deaths	Death Rates			SMR Ratio, PWJ/PWE
		Observed	Expected	SMR†	
0–1	4	2 32	1 82	127	4 28
1–2	7	4 06	1 87	217	1 03
2–3	1	0 58	1 90	31	6 97
3–4	2	1 16	1 96	59	1 15
4–5	1	0 59	2 02	29	3 72
5–6	1	0 58	2 11	27	8 26
Total	16	9 29	11 68	80	2 78

† Standardized mortality ratio = Observed deaths/Expected deaths × 100

TABLE 1—*Continued*

PRISONERS HELD BY JAPAN (GROUP PWJ)

Causes of Death	Deaths		
	Observed	Expected	SMR†
Cardiovascular	8	4.1	200
Tuberculosis	11	2.2	500
Malignant neoplasm	4	1.9	210
Digestive system diseases	4	1.1	360
Suicide	3	1.5	200
Accident	26	10.1	260
Other	2	4.4	50
Total	58	25.3	230

PRISONERS HELD IN EUROPE (GROUP PWE)

Causes of Death	Deaths			SMR Ratio, PWJ/PWE
	Observed	Expected	SMR†	
Cardiovascular	1	2.1	50	4.0
Tuberculosis	2	1.7	120	4.2
Malignant neoplasm		1.3		
Digestive system diseases	1	0.8	130	2.8
Suicide	2	1.3	150	1.3
Accident	8	10.3	80	3.3
Other	2	3.6	60	0.8
Total	16	21.1	76	3.03

MORTALITY OF CONTROL POPULATIONS AGES 20-44 FROM SAME THEATERS OF WAR

Years Follow up	Pacific Theater (Group WJ)				European Theaters (Group WE)			
	Deaths			SMR Ratio PWJ/WJ	Deaths			SMR Ratio PWE/WE
	Observed	Expected	SMR†		Observed	Expected	SMR†	
0–1	3	2.0	150	3.6	1	1.8	55	2.3
1–2	2	2.1	95	2.3	1	1.8	55	3.9
2–3	1	2.2	45	4.8	5	1.9	260	0.1
3–4	1	2.3	45	1.5	6	1.9	320	0.2
4–5	1	2.4	40	2.7	3	2.0	150	0.2
5–6	6	2.6	230	1.0	2	2.1	95	0.3
Total	14	13.6	103	2.16	18	11.5	160	0.5

morbidity leave increments of impairment. Among examples of evidence supporting this theory are radiation effects, in that morbidity induced by radiation exposure induces a proportional degree of aging over a wide range of exposure. For single exposures each roentgen received is equivalent to aging by 5–10 days, in terms of effect on humans, as extrapolated from studies of other species (Table 7). A relationship of proportionality to dose also applies over the range from 100 to 1500 r exposure when generation of tumors is used as a measure of radiation effect rather than shortening of life span.

Radiation exposure has not been evaluated critically directly in humans with regard to life shortening. Some of the fragmentary evidence on this point indicates that life shortening does occur and to the same extent as in laboratory mammals. With regard to generation of cancer, a factor contributing at least partially to total death rate and life shortening, the response to radiation is known to occur in humans to about the same extent as in other animals for the same exposure, and the onset of the disease occurs at the same fraction of life span after exposure. The implication that increases in late morbidity and mortality attributable to radiation effects are related to immediate injury is an important concept and a tool for further exploration of the mechanism of aging. The relationship between exposure and apparent aging is so significant that points both of concurrence and of lack of concurrence become important in considering the phenomena of aging.

Genetic selection effects, described earlier in terms of life table differences between genetic strains, are evidence of a correspondence between genetic factors and aging. Some rough guesses can be hazarded with regard to quantitative relationships between genetic state and life table units. For example, in the fruit fly, the average new mutation acquired in sufficient relative abundance through radiation exposure to permit analysis of effects imparts a 5 per cent fertility decrement per mutant carried, throughout the subsequent germinal history of that mutant. Morton *et al* (1956) have estimated the average number of undesirable mutants in the human population, either as discretely dysfunctioning genes or as the sum of minor genic impairments, to be about 5 per individual. If we assume 5 per cent impairment of health per gene (a parallel to the fertility loss in the fly), the result would be an average impairment of 25 per cent. This is, of course, a somewhat tenuous concept, not readily convertible to life span units.

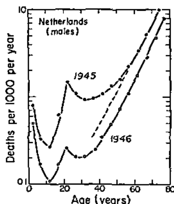


FIG. 7.—Effects of hardship on death rates of Netherlands males 1945–46.

From the study by Russell (1957) of the life span of the first generation offspring of irradiated male mice suitably recovered from acute effects of exposure, one may infer that the life span loss among the offspring of irradiated parents is roughly equivalent to the life span lost to the parents' generation from whole body radiation exposure. This bit of evidence provides an important linkage between increments of genetic change, radiation exposure, and equivalents of aging in cells of somatic tissues. A calculation based on a number of assumptions of varying degrees of validity—assumptions as to the life span reduction per roentgen of radiation, the carry over of this effect to succeeding generations, the mutation rate per gene per roentgen, the

number of genes in mammals, and the number of undesirable mutations per individual among humans—leads to the approximation that the adverse genetic burden is equivalent to some 7 years or so of physiologic aging This crude estimate may give some idea of the order of magnitude of the effect

VIII Childhood Health in Relation to Adult Health

Beginning at least a century ago death rates have been declining for all ages A

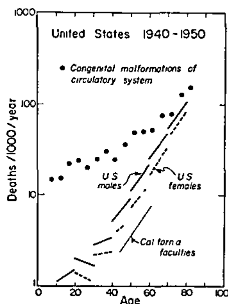


Fig 8—Death rates of various United States categories (1) cohorts of U S males 1940–50, (2) cohorts of U S females, 1940–50, (3) college faculty members, ages 20–64, California, 1949–51, (4) abstract population dying of congenital malformations of the circulatory system, U S, 1954–55 The wide difference between categories (3) and (4) is noteworthy

special feature of this change is that the gains have not been equally apparent in all ages of life at the same calendar time An especially pronounced instance of this kind is an effect observed in the vital statistics of Sweden, when soon after 1855 and again after 1885 early childhood mortality dropped rapidly without corresponding declines in adult death rates at the same calendar time After the intervals of time necessary for these cohorts of children to become adults, the population showed corresponding improvement in adult health Childhood mortality in Sweden thus becomes a good basis of prediction of adult mortality when considered from a predictive age in childhood to those same cohorts 45 years later (Jones, 1956*b*)

Correspondence of childhood mortality with adult mortality is especially strong in the cohort analyses of the northern European countries, these are the countries that have achieved the lowest death rates in all ages and, of course, a specially impressive gain in the lowering of mortality in early life This trend is also apparent in a limited cohort analysis for the United States (Fig 8) In this graph of death risk by age, cohorts of population are shown plotted over the 10 year span 1940–50 It is noted that at all ages, 1950 groups of males or females have a lower total death risk than do 1940 groups at the same ages An analysis by cause would show a close parallel to the cases presented in Tables 2 and 3 An examination of these tables, pertaining, respectively, to two selected age groups in the United States population of recent years and to the Netherlands male population, shows that the gain is distributed throughout the various causes of death even though the decline in tubercular deaths may account for a quarter of the decline in mortality Tuberculosis and rheumatic fever are the two diseases that have contributed most conspicuously to long standing adverse effects on health from early disease

Tuberculosis

If a life table is calculated for the population of those known to have died from tuberculosis, taking cognizance of the distribution of ages at death and throughout life in that population base (see Appendix A), it is found that, as one would expect,

their risk of death is considerably above that of the population at large (Jones, 1956*b*) The distribution of death risk by age for this subpopulation is always displaced by about 10 years from that of the general population from which it is abstracted This means that persons infected by tuberculosis and eventually classified as tubercular deaths have a life table similar to that of the general population except that the risk is advanced equivalent to about 10 years of life or aging The life insurance *Impairment Study* (Society of Actuaries, 1951) confirms a higher risk of death for those who have had an attack of pulmonary tuberculosis within the 10 years prior to policy issue, but those who have experienced a single attack at least 10 years before insuring appear to be at about the population average in comparative

TABLE 2*

DEATH RATES BY CAUSE SEX, AND AGE WHITE POPULATION, AGED 50-59 YEARS

CAUSE	MALE				FEMALE			
	50–54 Years		55 59 Years		50–54 Years		55–59 Years	
	1949	1954	1949	1954	1949	1954	1949	1954
All causes	12 421	11 468	18 695	17 430	6 792	5 949	10 200	8 788
Tuberculosis	0 578	0 243	0 693	0 314	0 133	0 056	0 150	0 059
Malignant neoplasms	1 979	2 031	3 184	3 377	2 299	2 177	3 139	2 887
Cancer of respiratory system	0 497	0 590	0 774	0 998	0 082	0 080	0 121	0 118
Cancer of digestive organs	0 773	0 704	1 337	1 192	0 632	0 544	0 993	0 851
Diabetes	0 145	0 126	0 242	0 213	0 182	0 133	0 406	0 303
Vascular lesions of central nervous system	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 938
All heart disease	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2 608
Ulcer of stomach and duodendum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 039
Accidents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 269

* Source Federal Security Agency (1940–55) for 1949 and 1954

TABLE 3*

DEATH RATES FOR MALES PER 1000 PER YEAR BY MAJOR GROUPS OF CAUSES
THE NETHERLANDS 1951 AND 1955

CAUSE	AGE INTERVAL							
	5–1		15 24		25–44		45–64	
	1951	1955	1951	1955	1951	1955	1951	1955
All internal disease	0 206	0 217	0 394	0 325	0 942	0 853	7 173	7 826
All infections	191	090	233	098	391	219	1 211	0 967
Trauma	0 283	0 290	0 370	0 417	0 417	0 396	0 663	0 702
Total	0 680	0 597	0 997	0 840	1 750	1 468	9 047	9 495
Changes, 1951 55	−0 083		−0 157		−0 282		+0 448	

* Source United Nations (1957)

mortality The life span effect of tuberculosis seems to depend upon the continuance of active infection in some degree Support for this view is seen in the dramatic improvement of general health in Japan in very recent times, though a causal connection would be difficult to establish, it is noteworthy that a rapid decline in tuberculosis deaths is associated with the improvement of death rates at all ages

HEART MURMURS AND RHEUMATIC FEVER

The life insurance *Impairment Study* (Society of Actuaries, 1951) reviews expe risk from cardiovascular disease is extraordinarily high in both groups, in keeping with the usual impressions concerning the linkage of heart murmurs with a tendency toward vascular accident Cerebral vascular disease is also elevated, but the surprising fact is the elevation of cancer risk

The three major causes of death in the general population are all elevated in association with heart murmur, so that an evaluation of aging with regard to the presence of a murmur suggests that this condition is roughly equivalent to an over all increment of aging, as gauged by the advancement of

TABLE 4

HEART MURMUR CASES REPORTED IN LIFE INSURANCE 'IMPAIRMENT STUDY (1951)

Group*	All Deaths			Malignant Neoplasms			Vascular Lesions of Central Nervous System			Heart and Circulatory Diseases			Digestive Diseases			Accidents and Homicides		
	Obs †	Ex ‡	SMR §	Obs	Ex	SMR	Obs	Ex	SMR	Obs	Ex	SMR	Obs	Ex	SMR	Obs	Ex	SMR
A	947	527 4	180	109	77 8	140	33	19 0	174	532	178 6	298	21	29 3	72	56	74 3	75
B	177	80 9	263	10	8 1	124	7	1 5	465	115	23 3	493	6	4 4	136	11	11 5	96
Total	1124	608 3	185	119	85 9	139	40	20 5	195	647	201 9	320	27	33 7	80	67	85 8	78
C	155	158 2	111**	14	18 7	75**	Not reported			72	49 0	147**	7	9 6	73	26	20 5	127

* Description of group classification of policyholders
Group A = Constant murmur without hypertrophy or rheumatism
Group B = Constant murmur without hypertrophy or rheumatism with history of tonsillitis or streptococcic infection
Group C = Inconstant murmur without hypertrophy or rheumatism
† Obs = Observed
‡ Ex = Expected
§ SMR = Standardized mortality ratio
** Differences significant at $p < .01$

rience in the pool of policyholders for a number of circumstances of physical impairment known at the time of issue of each policy In the groups affected with heart murmurs, it may be presumed that health appeared good in other respects, since they were granted insurance The difference between those with constant murmur and those with intermittent murmur may be assumed to be small A comparison is nevertheless made between these two groups, excluding those with cardiac hypertrophy or experience of rheumatism, and it may be seen (Table 4) that the presence of a constant murmur involves a significant increase of risk over the presence of an inconstant murmur As expected, the death risk of the major causes of death No suggestion is implied, however, that each cause of death is equally intensified in association with heart murmur, but the possibility that, on the average, some streptococcal involvement is associated with the occurrence of heart murmurs, even in the absence of rheumatic symptoms does suggest that some of the decline in death risks associated with improvement of childhood health may well be the average consequences of reduced frequency of streptococcal infections

The effects described for the cases of heart murmur without known rheumatism are intensified in the group with overt rheumatic symptoms It seems probable that

rheumatic fever complications exist in a continuum of grades of severity, so that late streptococcal infection effects in a general population may be considerably greater than those estimated from a description of the incidence of clinically evident complications of rheumatic fever The drastic long term effects of both rheumatic fever and tuberculosis in health and death risk throughout life span suggest that all the infectious diseases may have the same kind of deleterious effect If this be true, however, there is no estimate of the relative detrimental effect of each, nor is it known whether such long term effect would depend upon long lasting active disease as in the example of tuberculosis, or upon the aftermath of sclerotic changes in critical tissue areas, as in the case of rheumatic fever

IX Metabolic Events Known To Be Associated with Aging

DIABETES MELLITUS

Diabetes mellitus is a prime example of a disease induced by lack of a single hormone—in this case insulin Physiologic and pathologic changes subsequent to the onset of diabetes, however, may be vastly complicated Prior to the discovery of insulin, diabetes was typified by a high mortality throughout the survival period of the diabetic Following the discovery and use of insulin, mortality began to decline and has continued to decrease up to the present time The mortality rates in Table 5 have been estimated from survival numbers given by Joslin *et al* (1952)

Before the use of insulin, diabetes had a feature in common with cancer in that the death rate for any affected group was high, about 200 deaths per 1000 per year, and the rate was essentially unrelated to the duration of the disease or the age of the patient (Jones, 1956*b*) The high death rate thus did not increase with aging Subsequent to the employment of insulin, the death rate fell dramatically and concurrently became age dependent At the present time the excess mortality associated with diabetes is evenly distributed over the adult ages and is approximately 70 per cent above that of the general population, in units of physiologic aging, this is equivalent to about 6 years The tabulation of mortality risk in diabetic cases treated at the Joslin Clinic implies that diabetics using insulin were very close to normal mortality risk during the first 2 years of the disease and that they ' aged" more rapidly

TABLE 5*

MORTALITY OF DIABETICS DURING FIRST TEN YEARS OF THE DISEASE BASED ON CASES TREATED AT THE JOSLIN CLINIC

Calendar Period	Years of Diabetic State	Deaths per 1000 per Year
Pre insulin		
1897–1914	All intervals 0–10	213
1914–22	All intervals 0 10	192
Insulin era		
August 1922—December 1929	0 2	95
	3–10	147
1930–36	0–2	41
	3 5	57
	6–10	103
1944–51	0 2	20
	4–10	60

* Source Joslin *et al* (1952)

than the general population over the subsequent 8 years of follow up In this example the force of mortality must then be greater than normal, indicating an accelerated rate of aging analogous to the effects of chronic irradiation

BLOOD LIPIDS

Evidence accumulated over many years has linked serum cholesterol levels with arteriosclerosis, following the observations of Anitschkow (1914) At various periods in the study of lipid metabolism, each of the chemically determined categories of serum lipids has been associated quantitatively

with arterial disease Gofman *et al* (1949) introduced a major technical innovation that has resulted in an even more specific linkage between blood lipid levels and arteriosclerosis, since their extension of ultra centrifuge theory established a method of analytical separation of serum lipids in their native molecular states These lipids are found to be an array of lipoproteins, varying in both quantity and kind of com plex lipid fraction and in characteristic mo lecular weight With the aid of this tool the risk of recurrence of a vascular disease accident (Table 6) was shown to be de pendent upon the patient's serum lipopro tein level (Jones *et al*, 1951)

TABLE 6*

RECURRENCE OF MYOCARDIAL INFARCTION

Serum S_f° 12 20 L poprotein in Per Cent of Normal†	Recurrences per Patient Year of Observation	Recurrences per 1000 per Year
Less than 83	0/17	(0)
83–119	3/50	60
120–43	4/51	78
144–90	10/110	91
191 238	11/70	157
Greater than 238	11/61	180

* Source Jones et al (1951)
† Normal = 42 mg per cent

Other methods of appraising the relative risk of myocardial infarction associated with serum lipoprotein levels have been employed, including a direct prospective measure of this risk from individuals char acterized in their preattack state (Gofman *et al*, 1953) The distribution of lipid lev els in the general population base is con siderably different from that in the clinical population of survivors of myocardial in farction originally studied Observations on the general population lead to the conclu sion that the span of relative risks of oc currence of myocardial infarction extends from 0 2 of the average for the lowest 10 per cent to 3 0 times the average for the highest 10 per cent, classified on the basis of the fraction of low density serum lipoproteins having a flotation constant S_f° 0–400 (Gofman *et al*, 1953) This range corresponds to a fifteen fold variation in intensity of the vascular disease risk Other blood lipid measures are also significantly associated with enhanced coronary dis ease risk Dawber *et al* (1957) have shown that those in the upper ranges of serum cholesterol elevation incur six times as great risk of coronary disease attack as the group having the lowest cholesterol con centration

Reduction of the heart disease risk ap pears practicable, using dietary methods for lowering the disturbed elevations of serum lipoproteins (Lyon *et al*, 1955) Re versibility of the process by which lipids are deposited in xanthoma tuberosum lesions which is thought to be biochemically related to the phenomenon of arterioscle rotic deposition of lipid materials, has been observed during prolonged periods (6 months or more) of suppression of serum lipids through diet and heparin injection in such patients It is not known, however, whether the lowered risk of recurrence of myocardial infarction depends upon any particular phase of the dietary change De creased frequency of recurrence is at least associated with lowered lipid levels, the ac cumulated arteriosclerotic changes may not revert so quickly, if at all

X OTHER PHYSIOLOGIC STATES ASSOCIATED WITH ALTERED LIFE SPAN

The distribution of blood pressures in the population of those free of overt disease centers about a considerably lower value than in the groups of individuals who have survived myocardial infarction Estima tions of the relative probability of incur rence of myocardial infarction made on the basis of blood pressure suggest that blood pressure has about equal importance with serum lipids in the estimation of heart disease risk (Gofman *et al*, 1954, Dawber *et al*, 1957) Blood pressure and blood lipids are only very slightly corre-

'ated, so that their usefulness in predicting the risk is additive On the other hand, overweight, a factor of considerable importance as a basis of estimating life expectancy, may not supply additional information in that regard beyond the information contained in the lipid and blood pressure data, because of the strong positive correlations between overweight and either blood pressure or serum lipids

Other factors that are associated with life span differences are smoking, marital status, sex difference, differences between urban and rural life, and occupational factors The common feature of the effects of each of these factors is that the displacement of mortality rates associated with each persists to about the same extent throughout the adult ages available for comparison In each instance circular arguments arise as to whether excess mortality is the effect of the environment or whether the environment has been chosen by people *having intrinsically different health*

Space is not sufficient here to examine the complex structures of these current debates concerning what is cause, what is effect and what is random in the observed associations It is sufficient to point out that these group differences do exist and with remarkable reproducibility of the differential mortality in samples drawn from different places and times An interesting comparison may be drawn to summarize several of these associations, for example the single, heavy smoking male, sedentarily employed in a large United States city, may be compared with a married, nonsmoking female living in rural Scandinavia If all these factors are assumed to be independent and additive, one would predict a difference in physiologic age, and an approximately similar difference in life expectancy, of 20–35 years Other comparisons are equally striking in terms of life table displacements equivalent to aging 70 per cent overweight may be equated with 15 years' aging, a change from the 25th percentile to the 75th percentile of serum lipoprotein levels with 17 years' aging, the smoking of one package of cigarettes per day throughout adult life with 7 years of aging Other comparisons are given in Table 7

XI Evidence for Variation of Aging in Selected Populations

The occupational subgroups of England and Wales (Great Britain, 1954), are as varied in life table characteristics as the populations of different countries A subgroup whose death rate for any specified cause exceeds the national average generally shows an increased rate for other common causes If it were not for some challengeable uncertainties as to proper occupational classification in the tabulated deaths the evidence for physiologic aging differences between populations would be established by this striking evidence alone

Equally impressive differences in relative mortality at ages 20–64 are reported by P Buell (personal communication) Members of college faculties in California have a standardized mortality ratio of 30 (in this case, a highly significant ratio of 51 deaths to an expected 170) The ratio for teachers is also low, SMR = 64 (286 observed deaths, 443 5 expected) The mortality rates of all professional groups except musicians, architects, and pharmacists were well below average Occupations usually associated with overeating, namely, cooks and bakers, have SMR's of 184 and 134, respectively The large class of workers in occupations prescribing health as a prerequisite of employment and involving moderate exercise in their tasks has an SMR below 100 Of 28 groups in this class, 22 have SMR's between 50 and 93, while 6 have SMR's from 102 to 110 The SMR's of three groups working under distinctively rugged conditions involving heavy labor are stevedores, 134, blacksmiths, 163, and boilermakers, 147 This list is not presented as critical evidence of *specific group differences in aging, but it*

does demonstrate that large differences in mortality rates exist in selected subgroups

An extraordinary difference between subgroups exists within the non white population in the United States Seventy-five per cent of this population has a death risk more than four times as great as that of the remaining 25 per cent This difference is equivalent to 17 years' aging of the adversely affected group in comparison with the group experiencing the more favorable risk, while the mortality of the latter is lower than that of the white population (Jones, 1956*b*) Although the validity of

TABLE 7*

PHYSIOLOGICAL AGE AND LIFE-SPAN DIFFERENCES

REVERSIBLE		PERMANENT	
Comparison	Years	Comparison	Years
Country versus city dwelling†	+ 5	Female versus male sex†	+ 3
Married status versus single widowed divorced	+ 5	Fa [illegible]	
[illegible]		[illegible]	+ 2
[illegible]	− 3 6	[illegible]	+ 4
[illegible]	− 4 3	[illegible]	+ 3
[illegible]	− 6 6	[illegible]	+ 4 4
[illegible]	−11 4	Both mother and father [illegible] yr	+ 7 4
[illegible]	−15 1	Mother lived to age 80 yr	+ 1 5
[illegible] weight	− 0 17	Father lived to age 80 yr	+ 2 2
Smoking‖		Both mother and father lived to age 80 yr	+ 3 7
1 package cigarettes per day	− 7	Mother died at 60 yr	− 0 7
2 packages cigarettes per day	−12	Father died at 60 yr	− 1 1
[illegible]		Both mother and father died at age 60 yr	− 1 8
[illegible]ing [illegible] tions	+10	Recession of childhood and infectious disease over past century in Western countries	+15
Having average lipoprotein concentrations	0	Life Insurance *Impairment Study***	
In 25th percentile of population having elevated lipoproteins	− 7	Rheumatic heart disease evidenced by	
In 5th percentile of population having highest elevation of lipoproteins	−15††	Heart murmur	−11
		Heart murmur+tonsillitis	−18
		Heart murmur+streptococcal infection	−13
Diabetes‡‡			
Uncontrolled, before insulin 1900	−35	Rapid pulse	− 3 5
Controlled with insulin		Phlebitis	− 3 5
1920 Joslin Clinic record	−20	Varicose veins	− 0 2
1940 Joslin Clinic record	−15	Epilepsy	−20 0
1950 Joslin Clinic record	−10	Skull fracture	− 2 9
		Tuberculosis	− 1 8
		Nephrectomy	− 2 0
		Trace of albumin in urine	− 5 0
		Moderate albumin in urine	−13 5

* Source Jones (1956*b*)

† Central Bureau of Statistics (Statistiska Centralbyrån) (1917 1953) National Health Service of Denmark (1914, 1921 1937 1949) Federal Security Agency (1940-55)

§ Dublin *et al* (1951)

‖ Hammond and Horn (1954)

Gofman (1956)

** Society of Actuar es (1951)

†† This 70 per cent difference in distribution of lipoproteins, between 25 per cent versus 5 per cent highest is equivalent to a total of 25 years in relative displacement of physiolog c age

‡ As measured in 1900 These effects may be measurably less now as environment is changing to produce greater d ffe ences between parents and progeny

‡‡ Joslin *et al* (1952)

this observation may be questioned by some on the basis of the possible unreliability of reported ages in the non white population, nevertheless, this particular effect depends largely on the very high death rates in the non white population from ages 30 to 60 and the data for these ages are thought not to be materially affected by biased reporting of ages

XII Abstract Populations

Other select population subgroups can be identified that are meaningful in establishing individual differences in life span One of these is the group identified with congenital malformation as the cause of death The group was narrowed further for the purpose of this study being restricted to those having malformed circulatory systems Death rates were constructed for this select population using the method described previously (Jones 1956*b*) and further explained by Grendon in Appendix A In such a group predestined to have one selected cause of death the death rate from that one cause has about the same significance as deaths from all causes in the general population The method depends upon the distribution of ages reported at death so that one need only know that the sample is a reasonably representative cross section of the population in order to determine the mortality characteristics of the group Those dying of congenital malformation of the circulatory system have elevated mortality risks throughout life and on the average about three to six times the mean adult rates (Fig 8)

Comparisons of the subpopulations dying of specified causes (Jones 1956*b*) have shown that death rate from any one cause is on the average related to the population trend to high or low total death rate or to the intensity of other selected death risks It has also been shown that the rates pertaining to these abstracted populations support a concept of differing death risk for that particular cause in contrast to almost any other cause of death and that age specific death risks in any one kind of these abstract populations differ from country to country in a way that bears out the implications of death risk and mortality as rough measures of physiologic age Figures 9, 10, and 11 show the abstract death rates for males at age 58, for heart disease hypertension, cancer, and cerebral vascular disease Twenty nine countries are included in the comparison (Chile and Ceylon had to be excluded on the basis of

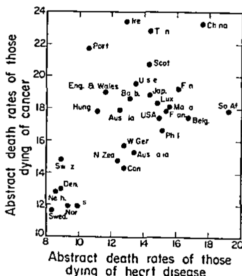


Fig 9—Correlation between death rates for heart disease and for cancer

gross inconsistencies in vital data reported in the *Demographic Yearbook 1957*) The relationship suggests relatively great differences among these countries in death risk at this age due to internal causes, indicating that aging has geographical difference

The trend of incidence of specific types of cancer by age, population sample and calendar years is important in considering the nature of the action of major causes underlying the occurrence of these cancers Upon examination of the vital statistics of the United States for any given calendar interval death rates due to cancer of the lung and bronchus and to leukemia are

seen to increase with age, except at very young and very old ages, moreover, at any given age, death rates for these causes have been increasing with calendar time (Dorn and Cutler, 1955, Gilliam and Walter, 1958) The former of these trends is ap parent, for example, in the slope of the broken line curves in Figure 12, the up ward trend of age specific rates with calendar time is seen in the successive displacement of these curves

It is instructive to use the method of co hort analysis in order to draw inferences concerning the nature of the unknown causes for the increase of these disorders Death rates for cohorts of our population are presented in Figure 12 for cancer of the lung and bronchus and in Figure 13 for

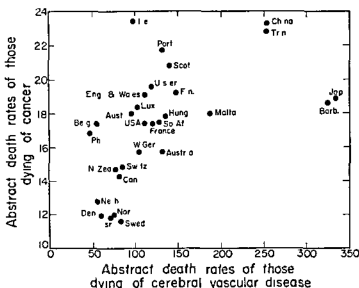


FIG 10 —Correlation between death rates for cerebral vascular disease and for cancer

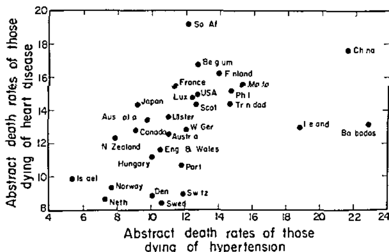


FIG 11 —Correlation between death rates for hypertension and for heart disease

leukemia The solid line curves of Figure 12 show that the death rates due to lung and bronchial cancer are increasing in absolute level at comparable ages, from one calendar decade to the next, and that the extent of the relative increase between any pair of ages is greater in cohort groups that are successively younger This trend is seen in a comparison of the slopes of the lines representing semilogarithmically the mortality rates of lung cancer for decennial cohorts born in 1850–1880 It will be noted that the slope becomes progressively steeper as younger cohorts are considered This kind of increase in risk is consistent with the hypothesis that whatever carcinogenic agents are acting have an accumulative effect and that successively younger cohorts are being exposed to these agents in progressively more intense degree As noted elsewhere there is a similar increase in the force of mortality associated with increasing levels of environmental radiation exposure suggesting that, with respect to lung cancer too the effective causative agents are acting continually are increasing in intensity with time, and are producing essentially irreversible changes

For those cohorts that were born in 1880–1900 it is noteworthy that the force of mortality for cancer of the lung and bronchus is relatively constant even though the absolute level of lung cancer for adults at similar ages increased five times between those born in 1880 and those born in 1900 Among possible explanations this marked increase in lung cancer, incurred without a significant increase in the corresponding force of mortality, suggests (*a*) that the causative factor may have ceased to increase in intensity with the passage of time but has been operative at a stable level of intensity from successively earlier starting ages in the younger cohorts, or (*b*) that some new environmental carcinogenic factor having relatively little accumulative effect may have come into operation (such a factor acting continually but having most of its injurious effects continually repaired, could account for the parallel displacement of the cohort mortality curves), or (*c*) that the proportion of persons in each age group who might die of lung cancer under the worst conceivable carcinogenic conditions is limited, in view of possible genetic susceptibility requirements and the competition of other causes of death (including other malignant neoplasms), so that, if that limit were being approached, one might expect the observed force of mortality curves to approach the boundary curve With reference to the last of these suggested alternatives, it is noted that the mortality rate doubling time for the cohort of 1850 was the same as that of normal human populations—about 8 5 years—and that the slope increased, rapidly at first and then more slowly, for successive decennial cohorts, and may be stabilizing at about 3 5 years doubling time, as found in the cohorts of 1880–1900 In no specific disease studied has a shorter doubling time than 3 years been observed

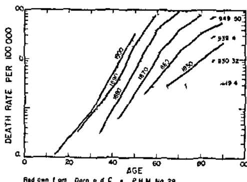


Fig 12 —Death rates for cancer of the lung and bronchus among U S white males 1914–50 *Solid lines* cohorts of 1850–1900 *Broken lines*, vital statistics of designated years

Throughout the period covered by the vital statistics of the United States, the probability of death due to cancer of the lung and bronchus has continued to increase The increasing slope of the force-of mortality curves suggests that the causative changes which precede the overt incidence of lung cancer are, on the average, occurring to a more intense degree (i e , at

a more rapid rate) in succeeding cohorts It is not known whether these changes are reversible or not, since the unrepaired residues of reversible deterioration would be similar in their effect on the force of mortality curves to the equivalent, smaller irreversible changes, but the magnitude of the net effect suggests that the degradative effects are probably largely irreversible Perhaps, if the environmental carcinogenic

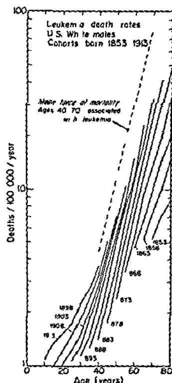


FIG 13—Death rates for leukemia among U S white males, 1923–53, by cohorts

circumstances were to be improved, at least the most recent increments of risk might be reversed

Analysis of the trends in leukemia incidence is instructive in the examination of the mechanisms of aging The great increase in incidence reported for this malignant disease has been widely publicized The associated death rates have increased for all ages, however, in the age specific incidence of the disease by calendar year, there has recently been seen a greater relative increase in the older ages This circumstance may be advanced as evidence that the increase in leukemia is real and not, as some have contended, the result of improvements in diagnostic efficiency with calendar time

Further evidence that the increase in leukemia is genuine may be found by organizing the data on death rates into cohort form The force of mortality relating to the leukemia risk among white males in the United States is presented on the cohort basis in Figure 13, derived from tabulations for 5-year calendar intervals as given by Gilliam and Walter (1958)

It is seen that, during a period in which the age specific death rates for this disease increased three- to eightfold, the force of mortality in each cohort remained at values typical of the human aging process—an interval of from 7 to 8 years corresponds to a doubling of the age specific death rates within the cohort Were the three- to eightfold increase attributable to a growing "popularity" of leukemia as the assigned cause of death, the slope of each cohort line so affected would be expected to rise markedly, to a doubling time of some 2–4 years

There are interesting parallels and contrasts between the lung cancer curves of Figure 12 and the leukemia curves of Figure 13 Leukemia shows greater uniformity of the force of mortality, nevertheless, an increase in its magnitude from the cohorts of the mid nineteenth century to those of the 1870's may be perceived In contrast to the lung cancer findings, however this change is relatively small As in the case of lung cancer, the displacement between successive cohorts appears to be diminishing, though to a less pronounced degree there is correspondingly less reason to hypothesize that some limiting level may have been closely approached

The association of leukemia with high levels of radiation exposure has led to much speculation as to the possibility that the observed national increases in leukemia death rates have been caused, at least in

part, by increases in average radiation exposure of the population Data adequate for the determination or disproof of such an association do not exist, but it is interesting to note that there is a close correspondence between the increases in leukemia and the increases in mean radiation exposure in the United States over the last 30 years Of course, many other environmental changes have occurred during the same period, and, even if the quantitative relationship between radiation exposure at high doses and the incidence of leukemia were extrapolated to the very low levels of average exposure that now prevail, the radiation effect would account for only a small fraction of the observed incidence of leukemia On the basis of such extrapolation, the validity of which has often been challenged, the sum of the radiation exposure incurred in the population up to 1925 could account for 5 per cent of the reported incidence, while 10 per cent of the increased incidence of 1950 could be attributed to the increased radiation exposure

If the leukemia effect observed were the result of radiation exposure, we might well expect that the force of mortality would have been changed, since radiation exposure in the general population has been accumulating progressively throughout the observational time This we observe not to be the case Since the increase in leukemia death rates is occurring quite regularly within each cohort, at approximately the typical rate of aging phenomena in general, there is no reason to think that the factors determining the probability of occurrence of leukemia differ from other aging factors with respect to the characteristic of exponential increase of each increment of deterioration The responsible factors—perhaps an environmental toxin that is becoming more abundant in each cohort—may be expected to differ, however, in integrated effect from one cohort to the next Unlike common environmental conditions that impinge upon all ages equally at any given calendar time, a factor possessing the described trait might be more intense in its effect on younger individuals The search for a factor that operates in some such way, whether an infectious process or a chemical toxin or some other mechanism, may afford a clue leading to the reduction of incidence of leukemia as an end state of the aging process

XIII Care as a Factor in Aging

Married status, whether compared to single, widowed or divorced status, appears to be associated with lowering of the mortality risk equivalent to the difference present within populations for those adults who are about 5 years younger (see Table 7) The difference between married and single may be largely attributed with great plausibility to the selection inherent in getting married among the single are those who, for reasons of poor health or low economic status do not marry Perhaps some measure of similar bias would be found in the divorced group to a lesser extent, but the widowed category should be relatively free of this effect, neglecting the small probability of some consequences of a spouse's illness The data indicate, however, that there are negligible differences between the different non married states and a pronounced difference between each of them and the married state From other examples of the action of environmental circumstances in effecting general changes in the risk of death, it appears plausible that the benefits of married status are linked to the better average care mutually given between spouses, the residence of the pair in an environment made favorable for healthful living by two more effectively than by one, and perhaps some lesser inclination toward the adventuresomeness of the non married It would follow, obviously, that some marriages are more effective in this regard than others

The factor of singleness in itself does not induce aging In a recent sociologic study of 30,000 Catholic nuns and 10,000 monks, the life expectancies of the members of these orders at age 45 were reported to be,

respectively, 1 2 and 2 2 years greater than for men and women in the general population (Scheinfeld, 1958)

Automobile driving can be cited as an example of care and environment interplaying to affect the end state of health In the United States male drivers under the age of 30 are causatively associated with a disproportionately large fraction of the total mortality from automobile accidents Perversely in this instance, the physical vigor of the young man, usually associated with good health probably leads him to take unwarranted chances that, on the average augment aging in the form of traumatic deterioration and in the ultimate form of termination of life Both outcomes are at least theoretically preventable

In considering ways to reduce the hazard to life and the aging increment imposed by the use of the automobile, it is interesting to contemplate that the commonly observed lower accident rates of married drivers may be related to the fact that, for a considerable fraction of the driving time two heads control the driving of the car instead of one, with the advantage that road hazards are much more likely to be detected Perhaps the net gain is greater than one might infer from the well known domestic discord generated by the same circumstance

Along similar lines one might speculate whether feminine caution and masculine lack of it may be the reason for the mortality pattern observed in Finland where the male rates are higher than those occurring in other Scandinavian countries, while the female rates do not disclose any such excess of mortality The cultural impression conveyed to a visitor is that these men display a diffuse indifference to casual risks including those associated with the automobile, and that the cultural pattern in this respect involves males of all ages One might also wonder whether the excess mortality of both sexes at all ages in Spain as compared to Italy might have its origin in cultural differences affecting the typical care accorded to children.

XIV A Summary of Evidence on Differences in Aging at the Same Chronologic Age

Although differences in the force of m tality have been pointed out in a specific cases, uniformity of the aging pr ess is borne out by evidence that the fo of mortality is seldom varied Under wide variety of circumstances, the force mortality has remained the same, for ample intensification of the death rate starvation and subsequent recovery to expected mortality when nourished, data pertaining to prisoners of war, a the relative displacements of mortality smoking overweight, marital status, urba rural difference, occupation, and physi impairment These differences do not, first hand indicate changes in the fo of mortality some of these situations ha not been sufficiently examined to be c tain of the magnitude and course of t force of mortality but only to be assur that a mortality change has occurred

In the comparisons of genetic differen morbidity induced by chronic irradiatio uncontrolled diabetes, persistently act infections and rheumatic fever, the natu of the aging phenomenon suggests that t factors causing an increase in the dea rate are continuing to act and are ir versible In that event, each increment continuing change is equivalent to an i crement of gain in the force of mortality

Cohort analysis of death rates at co responding ages shows that the death ra is progressively declining in most countri at most adult ages over recent calenda time While much of the effect observed attributable to a decline in the infectio processes, a large fraction of the decli in risk seems to reside with the interna diseases This conclusion is supported bot by evidence of decline in incidence and b the trend in apparent physiologic age a estimated for the abstract population considered

Examination of the invariant theory o age, which, for the most part, is based upo the constancy of the force of mortality

leads one to conclude that almost any environmental condition will alter the distribution of death rates by age in such a way as to maintain the same relative increase or decrease This means that, for the purpose of estimating relative risk, we may have already summed the advantageous or disadvantageous effects of a large number of environmental variables, such as smoking habits, family status, geographical region of residence, and exposure to accident hazards On the basis of the evident relationship between diet, blood lipids, and vascular disease, we can expect that control of the underlying metabolic variables alone may shift the average age specific mortality for males to achieve a gain equivalent to more than 10 years in relative physiologic aging, and eventually the gain may be greater than 17 years No amount of optimism will bring about these changes with dramatic speed The expected effect will be a continuing decrease in the death rates in the immediate years to come, yet the changes will have no effect upon the force of mortality

The little events that underlie the force of mortality are probably highly important steps in aging It is difficult to resolve their effects on aging in order to differentiate them from the average consequences of greater individual segments of change such as are produced by a metabolic failure, the occurrence of cancer, or the incidence of vascular occlusions that may kill critical peripheral segments of the body Considerable gain in health will be brought about by prevention of these and other massive increments of functional failure Among the problems of preventive medicine is an inevitable search for metabolic disturbances and toxins that underlie the probabilities of occurrence of these greater changes When the greater steps in aging have been reduced, it is highly probable that the smaller steps to aging will have been lessened, too

Whether one uses force of mortality, incidence of disease, or mortality rate by disease as an index, death risk, physiologic age, and aging follow the course of environmental improvements in time and place

APPENDIX

THE ABSTRACT AGE SPECIFIC DEATH RATE

ALEXANDER GRENDON
Donner Laboratory

The treatment of adjusted abstract age specific death rates devised by Jones (1956*b*) leads to a mortality rate J_c, characteristic of the disease c Because the concept is rather subtle, it may be helpful to view it from another aspect than that of the reference cited

If, within a population, there are n_i members of age i and this class incurs c_i deaths from disease c in the age interval i to $i + 1$, it would be of interest to determine a characteristic age specific death rate, as of the date of tabulation, based on that portion of n_i which is, in some sense, "subject to disease c" The members of n_i who are potential "c cases" cannot be determined in advance, but a useful estimate may be made in the following way

A summation of all the c deaths in the tabulation at ages equal to or greater than i, which we may designate C, divided by the sum of all deaths at ages equal to or greater than i, which we may call D, roughly measures the present probability that a member of n_i will die of disease c, hence, $(C/D) \cdot n_i$ is the number of persons in n_i who may be labeled "c-cases," based on

t

[illegible]

(1956*b*) in terms of an abstract age-spe-

cific disease specific death rate, c_i/C, adjusted by a correction factor The correction factor was obtained by dividing the age specific death rate (all causes), d_i/n_i, by the abstract age specific death rate (all causes) d/D, giving the factor D/n_i The product of c_i/C by this correction factor gives the result noted above It has been found convenient to refer to these abstract rates as "Jones functions"

The Jones function serves a useful purpose in comparing specific disease populations (e g, the "cancer population") with other groups with respect to physiological age and the force of mortality These are the purposes for which it was originated and for which it has been used Ideall

'subject to cancer' no matter what cause of death eventually ensues For a disease such as cancer, which typically runs a short course the loss of cases in the base by death from other causes is probably small but for many diseases, the competitive factor must be rather large In the present state of knowledge, it seems unlikely that a well defined, valid population base of this type can be established biochemically or clinically, so the Jones function may fill the gap for some time

This function should not be regarded as a measure of the seriousness of a specific disease from the public health viewpoint of course, since large values of the Jones function may be associated with diseases of minor importance in terms of numbers affected In its application to partial samples of a population, too, one must still take precautions to insure that the sample is representative of the population, since the "adjusting factor" can in no sense correct for sample bias

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XII

Psychopathology

EWALD W. BUSSE

This chapter is a summary of psychopathology as it relates to the aging person It is presented with a limited goal which is to give the reader a rudimentary knowledge of the symptoms, etiology, pathology, and treatment of mental disorders which are either more frequent in the advanced years of life or have special significance when studying patients who are advanced in years There are several books which treat the subject of psychopathology in greater detail, and, if the reader wishes to pursue further the known knowledge in this field, it is recommended that he turn to such sources of knowledge (Noyes, 1953, Mayer Gross *et al*, 1955, Moore 1955, Kaplan 1956, Ewalt *et al*, 1957)

I Definition and Elucidation of Specific Terms and Problems

Psychopathology is the branch of medical science which deals with the essential nature of mental disease, especially the causes, the structural and functional changes, and the manifestations of mental disorders In general, mental disorders are separated into two major categories The first are disorders caused by or associated with impairment of brain tissue function. This group is commonly referred to as the organic reactions The second group, disorders of psychogenic origin, is without clearly defined physical cause or structural change in the brain This group is usually referred to as functional disorders Although this separation into organic and functional is convenient and to an extent reasonable, it does not sufficiently acknowledge the fact that there are multiple etiological factors in most mental disorders The etiology in most instances undoubtedly is a complicated interaction of heredity, environment, and psychological factors It must be admitted that in many cases one of these three factors plays the major if not sole role in the production of the disease However, really to understand all the disease process and its implications to the individual and society, one must evaluate biological, social, and psychological changes This recognition has resulted in the emergence of interdisciplinary research teams attempting to identify and correlate the social, psychological, and organic factors which influence the mental processes in the aging person

An example of the interrelationship between socioeconomic status and organic changes has been reported by Busse and his colleagues These investigators found a striking difference in the number of "normal" brain waves in community volunteer subjects when separated by socioeconomic criteria (Fig 1) The subjects in the lower socioeconomic status had the highest percentage of dysrhythmic electroencephalograms Another finding which is of particular interest is the high incidence of focal disturbances which appear in the temporal lobes of many elderly persons, primarily on the left Further details re-

garding these findings can be found in the discussion of cerebral arteriosclerosis below The occurrence of this particular phenomenon may also be related to level of social adjustment. Observations, both old and new, are puzzling, and there is no direct relationship between the severity of the cellular change or the physiological pattern with the observable social and psychological functioning of the individual For many years a number of investigators have noted that there are individuals with gross defects or neuropathological changes within the brain who exhibit few or no obvious mental abnormalities during life (Critchley, 1929, Rothschild, 1937,

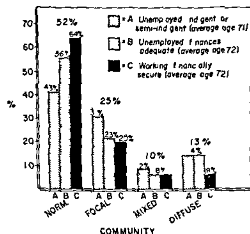


FIG 1 —Electroencephalographic changes correlated with socioeconomic status

1942) Our own studies utilizing the electroencephalogram as a criteria for physiological functioning indicate that some individuals who have a severe brain wave disturbance consistent with organic changes can maintain a satisfactory adjustment within the community (Busse *et al*, 1955, 1956, Barnes *et al*, 1956) (Fig 2) An other interesting example of this paradox is the syphilitic changes within the brain called "general paresis" It is generally conceded that the psychotic manifestations are the result of the syphilitic changes within the brain However, post mortem examinations of patients who have died without showing any psychiatric or neurological symptoms have revealed severe paretic brain changes Our own experience in these examples poses the question How and for what durations can an individual compensate for organic changes and maintain his adjustment in the community? The concept of stress as a causative factor is important in both functional and organic disorders Undue stress can exhaust physiological reserves and result in inefficient and unsuccessful compromises which do not

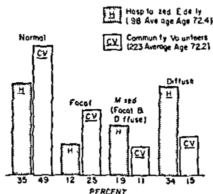


FIG 2 —Electroencephalograms of hospitalized and community subjects

successfully deal with the demands of reality

Since all individuals have experienced periods in their life span when they are not functioning effectively from a psychological viewpoint, one is constantly confronted with the question At what point is disturbed functioning to be regarded as disease? There is clearly no sharp demarcation between normal functioning and mental disorder Rather it is a gradual transition and can be considered as disease only when the suffering individual recognizes that he is disturbed or uncomfortable and requires help or when the individuals with whom he comes in contact decree that his behavior is no longer acceptable to them Therefore, society plays a large role in determining when and if a person is suf

fering from a mental disorder At the point when his behavior or expressed thoughts are no longer acceptable to them he will be considered sick and will be treated accordingly This reaction of society to the individual is extremely important in elderly patients Some segments of our society are much more willing to tolerate and protect the elderly individual while other groups are very willing to reject them at the first evidence of a decline in function

The magnitude and importance of the mental disorders of our aging population cannot be covered exhaustively However one should keep in mind that 27 per cent of all the admissions to public mental hospitals are patients with cerebral arteriosclerosis or other circulatory disturbances and senile disease (Fig 3) This group of patients makes up 13 per cent of the resident population of all mental hospitals (National Committee against Mental Illness, 1955) Thirty eight per cent of all new admissions into mental institutions are over the age of 60 (Fig 4) The mental diseases of the aged are clearly a very serious medical and social problem Treatment must therefore, not only include the prevention or eradication of the cause but the elimination or reduction of symptoms or the arresting of the disease

The diseases which will be discussed are presented in the sequence which is found in the *Diagnostic and Statistical Manual of Mental Disorders*, which was prepared by the American Psychiatric Association (1952) and is the standard nomenclature employed by the psychiatric profession This presentation does not include all the diagnostic categories but does include those important to aging because of (1) increased frequency in the later years, (2) etiological relationship to the aging process and (3) the serious impact upon the individual such as disintegration of personality or the development of a serious social or economic problem

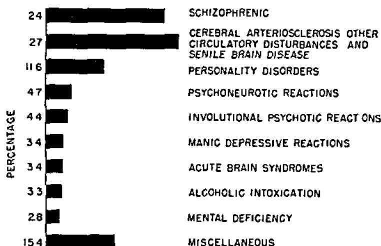


Fig 3 —Diagnostic distribution of first hospital admissions

II Disorders Caused by or Associated with Impairment of Brain Tissue Function

When a widespread disruption of physiological functioning of the brain develops in a person, an observer is likely to notice the following important alterations in the person's thinking and behavior The intellectual functions, which include comprehen

sion, calculation, problem solving, learning and judgment, are impaired Memory is spotty, and orientation of time, place, and person is faulty Emotional responses are easily elicited and are disproportionate or inappropriate to the stimulus This basic clinical picture, characteristic of an organic brain disorder, may be associated with other symptoms of a wide variety The type and severity of the symptoms are not necessarily directly proportionate to the extent of the physiological disturbance, as they are often influenced by psychological patterns of long standing and the particular psychological state of the patient at the time the physiological disorder develops

Organic brain disorders are separated for diagnostic purposes into two major groups —acute and chronic The term "acute" is not used to indicate a sudden onset of the symptoms but is meant to imply reversibility Both "acute" and "chronic" are descriptive terms which are unrelated to etiology, as the same causative agent may produce in one individual a temporary (acute) disorder, while in a second individual it may produce a permanent (chronic) disturbance

Acute Brain Disorders

The diagnosis of an acute brain disorder indicates that the patient is expected to or has recovered and that his physiological brain functioning has returned to normal Unfortunately, the possibility that an acute brain disorder may have a more prolonged adverse effect upon psychological functioning is often overlooked Guilt and embarrassment resulting from the thoughts which were expressed or the behavior which transpired during the illness often produce serious concern in the patient. Anxiety arising from this source must be recognized and relieved

Etiologically, the acute brain disorder is essentially a toxic reaction, and recovery comes as soon as the toxic agent is in some way eliminated

DISORDERS DUE TO OR ASSOCIATED WITH INFECTION

This reaction can occur in all age groups, but, although statistical evidence is far from adequate, it is reasonable to conclude that an older person possesses less physiological reserve and is, therefore, more vulnerable to toxic agents The onset of the symptoms may be insidious or rapid, and the first symptom that is likely to appear is fluctuations in memory with impairment of retention The level of alertness or awareness also fluctuates, moving from mild confusion to complete stupor Hallucinations can appear in all spheres of sensations Not infrequently they are bizarre and are very frightening to the patient The patient is to varying degrees cognizant of his inability to protect himself properly, and the patient misinterprets what is going on around him This increases his anxiety, and paranoid trends may emerge Verbal ability varies with the extent of the delirium Such patients weep easily, and their mood is dominated by fear and apprehension The symptoms may progress until the patient becomes stuporous In the return from stupor to awareness, all the previously displayed symptoms and new ones may appear

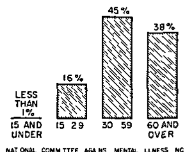


FIG 4—New admissions to mental institutions as related to age

The following findings are likely to be present The patient appears to be physically ill Vasomotor instability such as flushing, sweating, and rapid and fluctuating pulse are present, an elevated body

culation to the brain and by direct localized damage Postoperatively a delirium resulting from wet brain is not uncommon The correct diagnosis is clearly based upon a careful neurological examination and other laboratory procedures such as the electroencephalograph

III Chronic Brain Disorders

Chronic brain syndromes result from organic permanent impairment of cerebral tissue function The impairment of the brain at any particular stage of a chronic brain disease may partially subside but improvement is not possible beyond a point of irreducible brain damage For instance some chronic disorders are treatable to the extent that the loss of function may be almost imperceptible In addition the level of impairment fluctuates when observed over a period of time The fluctuations are the result of many forces which include intercurrent organic diseases and psychological and sociological forces Hence psychogenic disturbances are not infrequently superimposed on a chronic brain syndrome (Rothschild 1942) Therefore those symptoms which are predominantly psychogenic in origin may respond to treatment while the portion of the illness which is primarily organic in etiology cannot be treated and the individual restored to normal As was true of the acute brain disorders the chronic brain disorders are classified according to the cause of the impairment of brain functioning A number of the diagnostic categories are identical or similar to those which subdivide the acute brain sydromes The differentiation therefore is based solely on the criteria of the presence of permanent brain damage

The clinical history of an individual with chronic brain disease sometimes includes a history of a period of severe disturbance followed by improvement. This improvement may be due to an acceptable level of adjustment but there then follows gradual personality deterioration More often one observes a gradual personality change manifested by defects in retention of recent events more widespread memory defects difficulties maintaining proper orientation for time place and person defects in judgment and deterioration of personal habits In my opinion defects in judgment are probably widespread but are first noted with alarm when others are affected by some poor financial judgment that is made by the patient Faulty judgments involving interpersonal relationships which were previously well handled are then reported by interested observers If the history is carefully reviewed it is often found that mistakes in social judgment have existed for some time but have not been viewed with alarm by the patient s family or friends and are simply attributed to the idiosyncrasies of old age However the discovery of a financ al mistake crystallizes the recognition that judgments are defective in many spheres Emotional instability is reported and observed as a frequent manifestation of chronic brain disease It is possible that this symptom has both a physiological and a psychological explanation From a psychological viewpoint many patients are very much aware of their inability to function at their previous level of adjustment and this makes them vulnerable and sensitive to all threats In addition the physiological inhibiting mechanisms may be interfered with and hence a specific stimulus elicits a greater response

As previously noted psychogenic symptoms not infrequently overlay the organic disturbance The organic disturbance in many instances seems to reinforce the patient s need to utilize certain defenses which have for many years been essential features in the personality makeup of the individual The aggressive personality often becomes overactive quarrelsome and irritable The jealous suspicious person becomes clearly paranoid and the pessimistic patient becomes depressed

The increasing number of elderly patients being admitted to hospitals with a diagnosis of organic brain disease is a serious medical social and economic prob

lem Psychosis due to cerebral arteriosclerosis, other circulatory disturbances, and senile brain disease make up 27 per cent of first admissions to public mental hospitals (National Committee against Mental Illness, 1957, p 6) (see Fig 2) One of the most pressing needs is to develop preventive and therapeutic measures for those disorders which are now classified as chronic

DISORDERS DUE TO OR ASSOCIATED WITH INFECTION

The primary symptoms are like those of any other organic psychosis with slowing of the mental processes, errors in judgment capricious defects in memory behavioral changes and eventual deterioration into a state of mere existence Of the chronic infectious diseases, that of syphilitic origin seems to be the most influenced by previous personality The secondary symptoms are definitely colored by the patient s occupation education and previous patterns of social adjustment Since the advent of antibiotic medicines, the number of patients with chronic brain disorders due to infection is definitely declining This is true of the syphilitic group as well but it is believed that the possibility of this occurring in an elderly person must always be kept in mind, since currently this is the age group within our population which most likely escaped detection and proper treatment during the early stages of the disease Sir Walter Brain (1954) reports that, in patients over the age of 60, males are affected four times more frequently than females In a series of two hundred patients admitted to his service, 9 5 per cent were diagnosed as having neurosyphilis

Although so called delusions of grandeur were in previous years considered to be characteristic of paretic disorders, in our recent experience this has not been found in elderly patients with syphilitic brain disease Definite diagnosis rests upon the detection of a positive blood serology or abnormalities in the cerebral spinal fluid For detailed information regarding this complex disorder, the reader is referred to the appropriate references (Mayer Gross *et al*, 1955, Ewalt *et al*, 1957)

Brain infections may arise from local foci, that is, sites of primary infection within the head, such as middle ear, suppuration, and osteomyelitis of the skull The infection may be seeded from a distant focus, such as bronchiectasis, empyema, and endocarditis Infections which involve the meninges, that is, the covering of the brain, are attributable to a number of bacteria, including meningococcus, streptococcus, pneumococcus, tubercle bacillus, as well as the blastomycetes and other pathogens Viruses can produce encephalitis, and the most common forms of syphilis of the brain in elderly persons is so called general paresis

If the infectious process is continuing, an antibacterial or other appropriate medication is employed Penicillin continues to be the drug of choice for the treatment of syphilis The eventual outcome is difficult to predict, since the extent of reversibility cannot be determined until the completion of the treatment and elimination of infection

CHRONIC BRAIN SYNDROME ASSOCIATED WITH INTOXICATION

The usual history of such a patient includes a stage of acute toxic reaction during which the patient is delirious The delirium is reversible, but the patient is left with various degrees of brain damage which is permanent Over a period of years, the patient may show a gradual decline, terminating in eventual death Although it is estimated that 12,000 alcoholics die from chronic alcoholism each year, it appears to be primarily a problem of the middle aged male, as five of six alcoholics are males between the ages of 30 and 55 Elderly individuals do not have the same physiological reserve and are, therefore, more vulnerable to the effects of alcohol Depression, irritability, and weakness seem to be the most

common symptoms found in this type of chronic disorder

If the offending toxic agent has been eliminated the diagnosis rests upon the integrity of the history However, if the noxious agent is present in the individual or continues to be assimilated by the individual the diagnosis can be established by identifying the substance In most instances, some improvement will be noted by elimination of this toxin

The number of substances which can produce a chronic brain syndrome is very extensive and includes lead, carbon disulfide, carbon monoxide mercury manganese alcohol and other chemical substances such as bromides Arteriosclerotic patients have a particularly poor tolerance to bromides and develop toxic symptoms even though the blood content is relatively low

CHRONIC BRAIN SYNDROME ASSOCIATED WITH TRAUMA

Post traumatic personality disorders are observed in patients at all ages The complaint of headache and dizziness is not uncommon in young patients but the complaint of headache is less common in elderly persons This decline in the complaint of headache is not limited to the head injured group, as headaches decrease with advancing age Since the head is obviously a very significant part of the body and has increasing import in the body image of aging people, it is understandable that a host of psychogenic symptoms frequently confuse the post traumatic picture A serious medical legal problem frequently occurs in post traumatic cases and in elderly persons is further complicated by the fact that the trauma may aggravate a latent senile or arteriosclerotic brain disorder Trauma may be designated as the cause of the mental change when it may be in part or totally due to a latent chronic brain disorder

It has been observed in all age groups that, if trauma to the head occurs at a time or in a setting in which anxiety exists, the symptoms which follow will be significantly greater Such anxiety settings are produced by economic insecurity, occupational dissatisfaction, inability to secure work, and family tensions It is clear that these are anxiety situations which have a high likelihood of being present in individuals who have been retired or who are approaching retirement For this reason, the physician must be careful to discourage the patient from fixating upon the head injury as an explanation or a rationalization for his anxiety and his inability to cope with external threats

DISORDERS ASSOCIATED WITH CIRCULATORY DISEASE

Impairment of the blood supply to the brain can produce serious mental changes and is looked upon as one of the major problems in elderly persons "Circulatory disease" is a broad descriptive term and encompasses two major pathological processes The first is one which primarily is concerned with the changes of blood vessels within the brain and is usually referred to as cerebral arteriosclerosis There are some scientists who prefer the term "cerebral atherosclerosis" The second major disease process has its origin at a distance from the brain and initially involves the heart and kidney and is referred to as cardiorenal disease This pathological process produces widespread changes in blood vessels and affects the blood vessels of the brain Hypertension is present in such individuals

Cerebral arteriosclerosis—The appearance of symptoms which clearly indicate the presence of a brain disorder resulting from circulatory disease is on the average noted at 66 years of age The disease may appear in persons as young as 45 and may appear thereafter any time until the death of the patient Generally speaking, the symptoms are reported as having an abrupt onset, although it is apparent that, since the pathological process is a chronic progressive one, it is not the organic pathology that has an abrupt onset but the ap-

pearance of an incapacitating symptom In some instances, a gradual onset is reported which may be the function of a more careful observer rather than evidence of a more slowly advancing process However, one cannot ignore the fact that mental and physical stress often seems to precipitate the abrupt appearance of symptoms This is readily explained when one realizes that the patient may be functioning at a very marginal level, and, when an added stress is superimposed upon the existing physical changes, the organism breaks down and mental symptoms become apparent

It is generally believed that hereditary factors play a significant role in atherosclerosis and, therefore, cerebral arteriosclerosis The male seems to be more vulnerable to the arteriosclerotic process, and, although the exact reason for this is unknown at this point, it is possible that it is related to hormones It appears that estrogen and other female hormones play a protective role Cerebral arteriosclerosis is believed to be three times as common in the male as compared to the female Although the illness is a chronic one, one must remember that improvements do come about, often lasting years, if the superimposed illness or stress is removed

The changes of the blood vessels then result in occlusion of the blood vessel cutting off the blood supply in the localized area of the brain When this comes about, localizing signs and symptoms develop such as aphasia agnosia, apraxia, and Jacksonian seizures The disease process is a fluctuating course downward On some days the symptoms are more marked This is probably due to various changes within the circulatory system Since it is rare that the vascular changes only exist within the brain it is not unusual to have complicating events such as coronary artery disease, arteriosclerosis of the aorta, and kidney changes (*Young et al*, 1956) The duration of the illness is difficult to determine, and the average appears to be somewhere near 3 5 years However, since the widespread use of antibiotic medications, it is not unusual to find patients who have survived 16 years or longer Death usually results from overwhelming infections, an extensive hemorrhaging to the brain, or myocardial infarction

Some clinicians indicate that better than 50 per cent of cases with cerebral arteriosclerosis demonstrate their first symptomatology by developing suddenly a delirious picture, manifested by confusion, incoherence, and restlessness and not infrequently accompanied by hallucinations However, this delirious picture does subside and leaves the patient at a considerably reduced functioning level from which he gradually declines As previously noted during this gradual decline, intellectual processes involving memory and judgment are first affected Later this judgmental defect affects moral standards, and some individuals become very irritable, aggressive, and quarrelsome Not infrequently patients have some insight into the fact that they are losing some of their intellectual skills, and depressions then complicate the picture, and suicidal thoughts may produce a serious problem for the family and physician

It is recognized that there is often a difficult diagnostic problem in distinguishing cerebral arteriosclerosis from senile brain changes It is also clear that they can exist simultaneously However, these two disorders of the aged are a serious psychiatric problem In many state mental institutions better than 40 per cent of the patients admitted are over the age of 60 Of the first admissions, 33 per cent are considered to be senile or arteriosclerotic psychoses (Kallmann, 1950) Although at first glance it appears that there is an increase in the prevalence of these brain changes in elderly people, this may not be strictly true Since people are living longer, it may be that it is the same percentage developing the illness as in years gone by However, it is also possible that people are now surviving to the later years with vascular changes who in the past would have died at a much younger age However, Kolb (1942) has estimated that, if present admission rates

and population trends continue these two disorders that is cerebral arteriosclerosis and senile psychosis may be expected to show an increase of 200 per cent in the number of first admissions to state hospitals by the year 1980 The state of Illinois in 1955 reported similar findings and predicted that in the year 2000 67 per cent of the patient population in state hospitals would be over the age of 65 (Bettag 1955)

As will be discussed examination of the brain at autopsy indicates considerable differences in the pathology of senile brain disease and chronic brain syndrome resulting from cerebral arteriosclerosis However to distinguish these two diseases during the illness of the patient is a difficult problem and not infrequently is impossible Patients with arteriosclerosis as a rule do not show the profound physical and mental decay of the senile patient They are less likely to sustain fractures of bones If they are bedridden which is not infrequent the confinement to bed has resulted from neurological or cardiac failure Based upon an anatomical study diagnostic mistakes seem to be weighted in the direction of placing cases in the arteriosclerotic group when they should be diagnosed as senile Ehrentheil (1957) has published in a concise form the differential diagnosis of organic dementias and affective disorders Patients with cerebral arteriosclerosis often complain of headaches dizziness and have emotional outbursts Fainting attacks and convulsions are characteristic of cerebral arteriosclerosis Elevated blood pressures both systolic and diastolic are more likely to occur in the arteriosclerotic patient The memory defect in the senile patient is more likely to be diffuse, while in the arteriosclerotic it is spotty and fluctuates Both types of patients fabricate in order to make up for deficiencies The senile patient tends to have a greater problem with alteration in moral standards and sexual indiscretions If neurological examination reveals localized brain damage, this is sufficient evidence that the diagnosis of vascular disease is justified (Ehrentheil, 1957)

The electroencephalogram must be carefully evaluated as to its clinical implications because of the high incidence of temporal lobe dysrhythmias which are present in normal subjects over the age of 60 years (Fig 5) Focal slowing and spikelike waves are found in 25 per cent of control subjects Seventy eight per cent of the focal dysrhythmias are confined to the left temporal area, and 74 per cent of this group are found in the anterior temporal region Of the remainder 18 per cent are bitemporal and 4 per cent are found on the right Investigation to date reveals no evidence that this finding correlates with the presence of vascular disease cerebral dominance or psychological performance Therefore a temporal brain wave disturbance in patients over the age of 60 must be interpreted with caution until further facts regarding its etiology and significance are at hand

The problem of distinguishing cerebral arteriosclerosis from Alzheimer s disease and from Pick s disease is a challenging one Both Alzheimer s and Pick s diseases characteristically have a gradual onset Alzheimer s disease is characterized by diffuse intellectual impairment with a steady progression to profound mental deterioration Alzheimer s disease does not show intermittent periods of improvement Pick s disease is also an insidious process Both Alzheimer s and Pick s diseases have a much earlier onset than senile disorders

Cerebral arteriosclerosis or the hardening of the arteries of the brain is currently receiving considerable attention from medical science in an attempt to find a particular metabolic disturbance which results in the various changes within the blood vessel walls and the eventual narrowing of the lumen of the blood vessel (Ramsdell 1947 Lubarsch *et al*, 1957) (see Fig 6)

The ecology of cerebral arteriosclerosis and senile psychosis also deserves attention Dunham (1955) refers to his work which indicates that there is a high associa

tion between the organic psychoses of the elderly and areas of poverty He states that Mowrer s findings for Chicago in general support his but that the work of Dee for the St Louis area indicates that rates are scattered widely throughout the city Gruenberg (1954) reported that in the city of Syracuse there is an area characterized by high first mental hospital admission rates for cerebral arteriosclerosis and senile psychosis This area is characterized by high concentrations of multiple family dwellings and by a high percentage of people living alone This was a low socioeconomic area.

The progressive deterioration of mental functioning which results from this vascular change within the brain has been repeatedly referred to At the present time it appears doubtful that blood vessels that have been damaged can be restored to normal At this state of our knowledge it appears that preventive techniques are the more reasonable therapeutic approach and has resulted in the use of diets which restrict the intake of cholesterol and saturated lipoproteins (Lyon *et al* 1956, Albanese *et al*, 1958) However a number of investigators caution that it is premature to implicate excessive dietary fat intake as a specific cause of arteriosclerosis (Handler 1956 Lewis 1958) Anticoagulants are used as prophylaxis against cerebral infarction (Foley and Wright 1950 Millikan *et al* 1955)

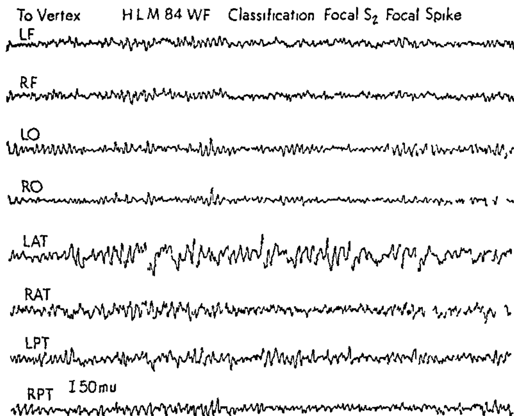


Fig 5 —Example of EEG temporal lobe focus

Many therapeutic approaches have been attempted all of which have obtained varying degrees of success Medications which

have been employed include brain stimulants such as Metrazol and Meratran (Barabee *et al* 1956 Kleemeier *et al* 1956) (Metrazol Knoll Pharmaceutical Company = pentamethylentetrazol Meratran Wm S Merrell Company = pipradrol hydracholide)

Enhancement of brain metabolism using L glutavite has obtained some success while tranquilizers such as Trilafon have also been successful (Katz and Kowaliczko 1956 Ayd 1957) (Trilafon Schering Corporation = perphenazine) Supplementary vitamins alone are reported to have some

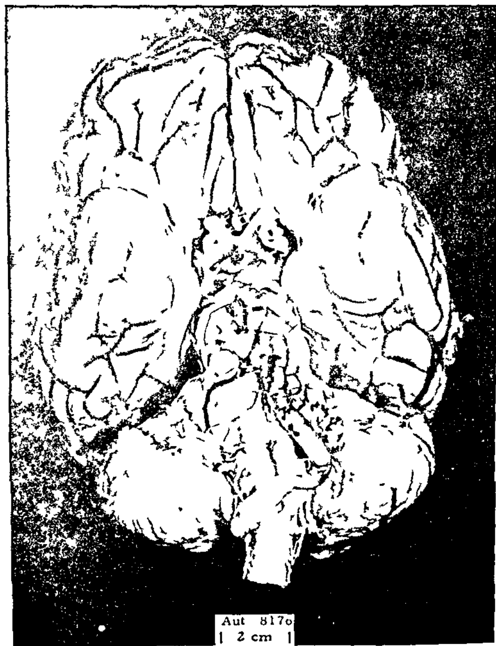


FIG 6—Cerebral arteriosclerosis Basal view of brain showing thickened sclerotic vessels with stenotic lumina. (Courtesy of Dr George Margolis [1959] Duke University Medical Center)

success (Barabee *et al*, 1956) Psychotherapeutically, a variation of approaches has been used, including individual psychotherapy, group psychotherapy, and attitude therapy (Allen and Clow, 1952, Goldfarb and Sheps, 1954, Ginzberg, 1955, Alvarez, 1957, Wolff, 1957)

Alvarez (1957) deserves credit for bringing attention of the medical profession to so-called little strokes The little strokes, that is, thrombosis of small intercranial arteries, do not produce any lasting aphasia or hemoplegia, but are usually characterized by a dizzy spell perhaps with nausea and vomiting, mental confusion, or a numb sensation in an extremity Cortisone has been used in some instances, but Alvarez does not feel that it is worthwhile He recommends that supportive measures be instituted and that the patient be relieved of excessive stress Alvarez feels that iodides seem to help If the patient is stout, he should be put on a reduction diet but hypertension should not be treated unless it is severe and constitutes a grave threat to the patient's life

Patients who have evidenced signs and symptoms of arteriosclerotic brain disease respond to a carefully regulated pattern of life and, if they can be assigned tasks which are in some way rewarding to them and within the limits of their abilities, it is very useful in preventing the appearance of irritability, overt manifestations of hostility, and depression with possible suicide As in all diseases, nutrition must be carefully maintained, alcohol intake should be prohibited and drugs which affect the central nervous system should be utilized with considerable caution Aminophyllin has been recommended for the relief of dizziness, headache, insomnia confusion, and delirium

Cardiorenal disease —Symptoms of circulatory disturbance are commonly observed in this disorder The sudden appearance of focal cerebral disturbance indicating a cerebral embolus is not uncommon Hypertension, evidence of kidney failure, and cardiac decomposition frequently give rise to this disorder. The onset of the disease is frequently noted when a stroke develops Such apoplectic strokes are often associated with the loss of consciousness followed by confusion or delirious periods. As the delirium improves, irritability, personality changes, and memory disturbances become apparent Insomnia with nocturnal restlessness produces a problem not only for the patient but for the family and hospital personnel In 1954, Foley reviewed 1050 autopsies, examining the brains of the patients over the age of 70 Foley found that 17 per cent of the brains indicated recent infarcts Twenty-six per cent showed evidence of old infarcts, and another 6 per cent had a combination of old and recent infarcts Of the patients with recent infarcts, an attempt was made to determine how many were directly responsible for the death of the patients It appeared that approximately 68 per cent of the recent group died from the brain hemorrhage However, this made up less than 10 per cent of all the patients studied

DISORDERS ASSOCIATED WITH DISTURBANCE OF METABOLISM, GROWTH, OR NUTRITION

Chronic brain syndrome associated with senile brain disease (senile psychosis) — Senile brain disease is a diagnostic category in which symptomatology may vary from mild to severe The mild cases may manifest a self centering of interests, difficulty in assimilating new experiences, and mild disturbances of emotional equilibrium. Deterioration may be minimal, but, superimposed upon this organic state, psychogenic, psychotic, neurotic, or behavioral reactions are not unusual and may be the cause of the more disturbing symptomatology A number of classic examples of senile dementia are found in the English literature Jonathan Swift's description of the "Struldbrug" in *Gulliver's Travels* is accurate and colorful P G Wodehouse's portrayal of Lord Emsworth is another such example

In contrast to cerebral arteriosclerosis, *senile dementia is more common in women*, the ratio of women to men being 2 to 1 The age of onset is somewhat later than that encountered in arteriosclerosis, usually not appearing until after the age of 60 As is so common in organic brain disease, the deterioration which affects judgment produces serious repercussions Attempts have been made to group patients with senile dementia into relatively distinct categories The symptomatology, characterizing the patients in such categories, does not appear to be the result of organic change but is rather the result of the emergence of long standing personality difficulties or patterns of adjustment Approximately 50 per cent of patients follow a pattern of simple deterioration Why this large segment shows relatively little other than deterioration is open for speculation No dramatic events accompany the illness and, since these people do not produce a serious disturbance in the community many of them are not brought to the psychiatric hospital until they have reached an advanced stage of senile mental deterioration However, the other half of the patients with senile dementia present complications which include depression, agitation, paranoia, or schizophrenic like symptoms Paranoid reactions are the most common and constitute 15–25 per cent of the diagnostic category Unfortunately, this can be a very sad development for the patient as well as for his family, as the patient will become suspicious of his family and often reverse commitments which he has made to his family, will change his will, and will do many other things which are very upsetting to those around him who have loved him

Senile dementia is accompanied by other evidence of exaggerated aging affecting the entire body There is a general wasting of muscles, shrinkage of the soft tissue, loss of elasticity of the skin, thinning and graying of the hair, and easy fatigability The gait is unsteady and speech disturbances are common

The course of the illness with a progressive mental and physical decay may extend over a variable period of time The onset of symptoms until death has varied between less than 1 year to 11 years or more Because of the unsteadiness of gait and the muscular weakness, this group of patients is likely to fall and complicate their difficulties by a fracture, particularly of the neck of the femur

Skill in differential diagnosis primarily revolves about the separating of senile dementia from cerebral arteriosclerosis The similarity and contrasting signs and symptoms of these two disorders have been discussed in the section dealing with cerebral arteriosclerosis Since toxic psychoses usually have an abrupt onset, this is not a particular problem when the toxic reactions are compared with senile dementia However, since depression can accompany senile dementia, it is somtimes necessary to distinguish this particular syndrome from the involutional depressions The primary difference in these diseases is concerned with the extent of intellectual impairment. Psychological testing can be of help

The cause of senile dementia is not adequately understood at this time, but the anatomical changes which accompany this disorder are characteristic There is shrinkage of the cerebral cortex, with widening of the sulci, and there is slight or moderate fibrous thickening of the pia arachnoid Although the blood vessels are not the major source of disturbance, many large vessels in the brain will show atheromata. Microscopic examination of the brain reveals shrinking and atrophy of nerve cells, Nissl s cell sclerosis, lipoid accumulation in the cells, and perforation of micro and macroglia. So-called senile plaques (Fig 7) and the fibrillary neuronal alteration of Alzheimer (Fig 8) are the microscopic features of this illness (Weil, 1945, Margolis, 1959)

No specific treatment is known for the prevention or reduction of the pathological changes underlying senile dementia As was mentioned in the section dealing with cerebral arteriosclerosis, a number of medica-

tions have been tried, including Metrazol Meratran and L glutavite (Barabee *et al* 1956 Katz and Kowaliczko 1956 Ayd 1957)

Cameron has reported the use of nucleic acid in aged patients with memory impairment Desoxyribonucleic (DNA) and ribonucleic (RNA) acids were injected into twenty three patients The diagnostic category into which these patients fall was not given and no details are given as to the evaluation of memory impairment A 10 per cent solution was employed and the usual route of administration was by intravenous injection All twenty three patients showed a favorable response, and in 50 per cent the results were considered good The best results were obtained in patients having severe memory deficits and marked confusion The side effects were minimum (Cameron 1958) Treatment must be concerned with the maintenance of adequate nutrition and the provision of environmental influences and forces which will allow the patient to adjust with as much comfort and happiness as is possible under these very adverse circumstances Much can be accomplished by environmental and psychotherapeutic means to reduce the psychogenic overlay of senile dementia For a more thorough discussion of this very important point one is referred to the publications of Goldfarb and others

ALZHEIMER S DISEASE

This illness was described by Alois Alzheimer in 1906 It is considered to be a presenile dementia the average age of onset is approximately 54 years However there is evidence that Alzheimer s disease should be considered a specific entity unrelated to age (Neumann and Cohn 1953) Occasionally it begins in the fourth decade of life but may appear in the early sixties where it is easily confused with organic dementias of senility It is probably the most common of presenile dementias as it is found in 4 per cent of the autopsy material in a psychiatric institution (Rothschild 1936) Its sex distribution is in favor of females the ratio being 3 to 2 Although Alzheimer s disease is not clearly a familial disorder families in which a hereditary predisposition exists have been reported in the literature (Lowenberg and Waggoner 1934 McMenemey *et al* 1939) Although the pathological findings are characteristic it is conceivable that a multiple etiology may account for this discrepancy



FIG 7—Senile plaque This change is demonstrated in a periodic acid Schiff hematoxylin stain to demonstrate its mucopolysaccharide nature (Courtesy of Dr George Margolis [1959] Duke University Medical Center)

in genetic findings (Lowenberg and Rothschild 1931) As is characteristic in all organic disorders there is a gradual intellectual deterioration However in spite of the loss of memory illogical reasoning etc insight is often preserved in patients with Alzheimer s disease which results in a distressing awareness of impending insanity As neuronal destruction continues speech becomes seriously disturbed and involuntary movements of the arms and legs are frequently observed Epileptic seizures can develop and after each seizure, a more

rapid progress of the mental deterioration is apparent

Alzheimer's disease must be distinguished from Pick's disease and from senile arteriosclerotic brain disease In comparing Alzheimer's disease to Pick s disease, the patient with Alzheimer s disease appears to be overactive as compared to the loss of initiative in Pick s disease Emotional distress and agitation are more common in feature is the degeneration of nerve cells and the appearance of neurofibrillary tangles arranged in the forms of whirls and baskets Senile plaques are usually present as well as this characteristic change For a detailed description of this pathology, one is referred to the standard texts and publications on the subject (Lowenberg and Rothschild, 1931, Weil, 1945, Margolis, 1959)



Fig 8—The Alzheimer fibrillary neuronal alteration Two stages of this process are demonstrated with the King silver impregnation technic (Courtesy of Dr George Margolis [1959] Duke University Medical Center)

Alzheimer's disease Air encephalographs reveal diffuse cortical atrophy as compared to the circumscribed cortical atrophy characteristic of Pick's disease (see "Pick's Disease" below)

Grossly, the brain shows a generalized atrophy, and superficially the cortex appears similar to that seen in cases of senile dementia Microscopically, the significant

The course of the disease is progressively downward with an invariably fatal conclusion The duration of the disease varies between 2 and 10 years and sometimes more The average is usually believed to be approximately 4 years No specific treatment is known for this disorder, and symptomatic and environmental measures are the sole relief that can be offered

PICK'S DISEASE

Pick s disease is generally characterized as a presenile dementia This classification may be a misleading one since it is doubtful that it is the result of the premature onset of an aging process Presenile refers to its time of onset during the life span. The age of onset may be as early as the fortieth year and the average age is apparently 54

The designation of this disease is attributed to A Pick who first published his work in 1892 Pick s original purpose was to illustrate the different types of aphasic manifestations which can occur in senile brain diseases It was really the efforts of other writers that established Pick's disease as a distinct clinical pathological entity Pick s disease is rare being much rarer than Alzheimer s disease The incidence and the prevalence in the general population is unknown to me However Neumann in 1949 reported that it was found in 0 2 per cent of the autopsy material of a mental hospital The female male ratio is 2 to 1 There is considerable evidence in the literature that Pick s disease is a specific heredodegenerative process which is not associated with rapid progression in a normal aging process Articles have appeared in both the European and the American literature and in the families that are reported in these articles there appears little doubt that the condition within these families behaved as a Mendelian dominant character (Lowenberg *et al* 1939 Sanders *et al* 1939 Delay *et al* 1945) The illness itself is seen as a slowly progressing dementia and the symptoms which develop are mainly those associated with the focal cortical lesion characteristic of this disorder The focal lesions which are primarily seen are aphasias apraxias and agnosias The insidious intellectual impairment is characterized by distractibility easy fatigability and a peculiar inability to deal with new problems and situations even though they are quite simple Memory is at first little involved but interest and attention show marked fluctuation during the course of the illness Depressive states are rare but emotional reactions are reduced and are blunted. As deterioration continues restlessness aimless activity and talkativeness can develop Since the talkativeness may be associated with various types of aphasia speech may be meaningless and a hopeless jargon As emotional blunting continues apathy is the usual pattern although *mild euphoria can appear* Hallucinations delusions and confabulations do not belong to the clinical picture of Pick s disease As noted above the focal signs are the primary symptoms with aphasia being the most frequent In the final stage of the disease paralysis contractures and epileptiform *seizures are often present*

In distinguishing this disorder from senile dementia many factors must be taken into account These include the earlier onset of the disease the possibility of hereditary features within the family of the patient and the characteristic symptoms of focal cortical damage usually frontal or temporal in origin Since epileptiform seizures seem to appear relatively late in the disorder they are of little diagnostic value, but in this stage of disorder it has been reported that patients develop peculiar attacks of muscular hypotonia The mental symptoms of apathy inattentiveness and a total lack of insight are useful diagnostic features Pneumoencephalographic studies will reveal the areas of localized atrophy Other laboratory studies are of very little value EEG studies are inconclusive (Delay and Desclaux 1945)

The contention that etiologically Pick s disease is a heredodegenerative process rather than an accelerated aging process is a reasonable one The morbid anatomy reveals atrophy involving both gray and white matter which is localized to one or more lobes or parts of the brain (Fig 9) The localization of the atrophic area varies The most frequent is frontal involving both poles the anterior third of the frontal lobe or particularly the orbital surface (Spatz 1937) The precentral convolution

is intact The second most frequent involvement is found in the anterior portion of the insula and the corpus callosum It is usually more pronounced on the left than on the right The third most frequent in occurrence is bilateral temporal involvement Here, the second and third temporal convolutions are the most involved Combinations of frontal and temporal atrophies are encountered, but the rarest is a unilateral frontal atrophy Occasionally, the that there is atrophy of the cell body, pyknosis of the nucleus, and there is a distinct type of neurocellular degeneration characteristic of Pick's disease The typical Pick cell is a swollen cell which has enlarged and become round in shape Nissl's bodies have disintegrated, and the cytoplasm appears homogeneous in appearance There are peculiar inclusion bodies in the cytoplasm which are the size of the nucleus of the cell and often larger This enlarged



FIG 9 —Pick's disease Mid-sagittal view of brain demonstrating characteristic atrophy of the frontal and temporal lobes and resultant dilatation of the ventricular system (Courtesy of Dr George Margolis [1959], Duke University Medical Center)

atrophic processes first appearing in the frontal or temporal areas make an appearance in the parietal and occipital lobe as well as the basal ganglion However, it is very rare to find exclusively areas of atrophy in the occipital and parietal lobes or in the corpus striatum Microscopically, the atrophic areas reveal a loss of nerve cells, with serious disorganization of the normal cellular lamination There apparently is variation in which of the layers is the most seriously involved When the nerve cells are closely inspected, it is found cell, although an interesting finding, is not always found in the atrophic cortex of Pick's disorder However, iron pigment is found in an abnormal amount in atrophic areas as well as in other parts of the brain. The blood vessels show no changes, and senile plaques of senile dementia and the neurofibrillary changes of Alzheimer's disease are not as a rule part of the picture of Pick's disease.

The duration of Pick's disease seems to vary from 2 to 11 years, with an average duration of approximately 5 years.

Throughout this time there was a gradual physical decline as well as the neurological and psychiatric symptoms previously described There is a gradual general physical decline and as the patient becomes confined to his bed, infections become more numerous, and intercurrent disease usually terminates the life of the patient. There is no known treatment for this disorder, and the therapeutic regime must revolve around adequate supportive health and environmental measures

IV Disorders of Psychogenic Origin or without Clearly Defined Physical Cause or Structural Change in the Brain

Involutional, Affective, and Psychotic Depressive Reactions

These three types of reactions can present a clinical picture under specific circumstances which closely resemble one another All include symptoms of depression

Clow and Allen (1949) found in 60 per cent of the patients over the age of 60 admitted to the psychiatric unit of a New York hospital a predominantly depressive mood. In the group of 365 patients, 65 per cent had functional types of mental illnesses, while only 35 per cent had symptoms usually associated with organic brain changes In the functional group, 80 5 per cent were essentially depressive in nature and were without clinical evidence of organic mental symptoms Of those patients with organic brain changes, only 27 per cent showed a conspicuously depressed mood When organic deterioration was advanced, less than one third had a predominantly depressive affect In most depressed patients the outstanding emotional response was irritability rather than depression

INVOLUTIONAL PSYCHOTIC REACTION

In 1953 involutional psychotic reactions constituted 4 4 per cent of first admissions to public mental hospitals (National Committee against Mental Illness, 1957) This depressive reaction is associated with the alteration of the endocrine system, which determines the capacity and extent of sexual interests and ability to reproduce Symptoms of an involutional nature can occur which do not reach the magnitude of a psychotic pattern In many females during the so-called change of life, a variety of complaints develop, including feelings of discomfort, restlessness, fatigability, and other somatic complaints Transitory crying spells, vasomotor instability, with so-called hot flashes or hot flushes, are widely accepted as evidence of the onset of the menopause That a similar climacterium can occur in the male has been a subject of considerable debate Undoubtedly, there is a decline in sexual function and reproductive capacity in the male, and it would seem reasonable that in some individuals this could occur at a more rapid rate than usual which could produce psychic disturbances However, the psychotic reaction of the involutional period is more common in the female, the ratio being 8 to 3 Genetic studies of the incidence of involutional psychosis indicates that, if one twin becomes sick, the expectancy rate is 6 0 in the dizygotic co twin and 60 9 in the monozygotic co twin (Kallmann, 1950) The reaction tends to have a prolonged course and history reveals that, with the onset of physiological evidence of the menopause, the patient gradually becomes more worried, has greater difficulty sleeping, and becomes very anxious and agitated. Guilt appears with self deprecation and feelings of worthlessness As the psychotic pattern continues, delusional ideas can develop, while a limited number of patients will develop all sorts of paranoid thinking as a defense against the depression This reaction is more common in individuals who have personality traits of meticulousness and compulsiveness (American Psychiatric Association, 1954) In addition to the features mentioned previously, these patients show a gradual restrictive alteration in their personality They gradually reduce their number of outside in-

terests and become much more interested in themselves and their family Originally an attitude of martyrdom is not unusual and the restricting of their interests can lead to extensive hypochondriacal patterns The severity of the clinical picture can vary widely For example agitation can be mild or severe Ideas of worthlessness may progress to a desire to die and to active suicidal attempts

Because of its similarity to other types of psychotic depressive reaction this diag nosis is limited to those individuals who give no previous history of a manic de pressive reaction and who are manifesting physiological changes typical of the involu tional period

Undoubtedly the physiological capacity of the central nervous system to adjust to the endocrine changes varies from one per son to the next It has been recognized for some time that the decline in the estrogens in the female makes the nervous system more responsive and vulnerable to certain stress stimuli and the release of adrenalin and noradrenalin From a psychodynamic viewpoint the involutional psychotic reac tion is more strongly linked to a conflict in the sexual sphere than other depressive reactions of the latter phase of the life span The menopause is certainly concrete ev dence to the woman that she is altering permanently her sexual capacities For a woman who has failed to resolve neurotic conflicts and achieve full sexual satisfaction or has failed to satisfy her maternal drives, the menopausal period is filled with re grets doubts guilt and a feeling that she is being punished for previous behavior For a more complete discussion of psycho dynamics the reader is referred to the standard texts of Fenichel (1945) and English and Finch (1954)

The treatment of an involutional reac tion can be separated into hormone re-placement therapy drug therapy, electro convulsive therapy and psychotherapy It is apparent that there is no single therapeu t c approach which will achieve recovery in the majority of cases Each case must be individually understood and treated It has been observed that certain types of pa tients with involutional psychosis respond to estrogen therapy Others are resistant and require electroconvulsive therapy Pa tients not sufficiently disturbed to require hospitalization will often respond to care fully planned environmental and psycho therapeutic approaches

AFFECTIVE REACTIONS

This disorder is included in this discus sion for the sake of completeness This diagnostic category includes all the various types of manic depressive reactions The manic depressive reactions are fundamen tally marked by severe mood swings and a tendency to remissions and recurrences The manic period is characterized by ela tion or irritability, with overtalkativeness flight of ideas and increased motor activi ty followed by a return to a base line of a reasonably normal adjustment or by a swing in the opposite direction to that of depression These swings can follow a wide range of patterns in both duration and di rection The depressive periods may be severe progressing to a depressive stupor That a hereditary factor is present in this disease has been known for many years Prognostically Rennie (1942) reported that 93 per cent of the patients recovered from the first attack but that 79 per cent had recurrences The duration of each at tack is difficult to predict but ultimate recovery is rarely in doubt. However, pa tients who experience their first manic de pressive episode after the age of 40 years have a much poorer prognosis than those with an earlier onset Attacks of excite ment occurring after the age of 40 years are much more likely to be followed by a state of chronic mania The possibility that this poor prognosis is related to organic changes must be kept in mind but has not been established

PSYCHOTIC DEPRESSIVE REACTIONS

This diagnostic category is utilized for those patients whose depressive reaction is

not related to involutional changes and whose history indicates no previous mood swings suggestive of a manic depressive type of life adjustment. This reaction can be related to the presence of environmental precipitating factors. For this reason, it can be referred to as a reactive depression. That is, the depressive period is in response to some relatively recent life event. Elderly persons are particularly vulnerable to this type of reaction, since they are in a period in life in which they are likely to have more serious and frequent losses to their self esteem and threats to their previous way of life adjustment. A more detailed description of the psychodynamics involved in such a reaction is found under the discussion of depressive reaction of a psychoneurotic type. The differentiation between a neurotic and a psychotic reaction is often difficult and primarily centers about (*a*) the extent to which the individual withdraws from reality and is unable to test reality and (*b*) the unwillingness upon the part of the patient to recognize that he is not wholly responsible for the loss of his self esteem and that a certain measure of restoration is possible with the help of others. The prognosis of these patients is directly related to the presence or absence of certain malignant symptoms such as severe hypochondriasis, intractable insomnia ruminations particularly of a suicidal type, and the development of delusional material.

Paranoid Reactions

This diagnostic category excludes those reactions which are more properly designated the paranoid type of a schizophrenic disorder. Paranoid reactions in elderly persons are not infrequently combined with organic losses. This has been previously mentioned. However, if the patient is to be placed in this diagnostic category, one would have to demonstrate that intelligence is well preserved and that the persistent paranoid symptoms are consistent with the emotions of the patient and his behavior. It is clear that such a reaction is more likely to occur in the setting of a predisposing personality, that is, a person who for some time has been sensitive and suspicious and likely to blame others for his failures. When in the advancing years of his life, changes develop which he interprets as failures, he does not view them realistically as part of an inevitable pattern or a social change. Rather he denies that there is any realistic basis for these failures and attributes them to the vengeful strivings of other persons. Many of these patients not only feel generally persecuted but often consider themselves to be endowed with special or unique abilities. They not infrequently feel that the younger people around them are jealous of these unique abilities and that the younger persons would fail if asked to compete on an equal level with them. The patient, therefore, feels that all sorts of measures are taken against him to frustrate his attempts to utilize his superior qualities. According to Mayer Gross *et al* (1955), paranoid disorders in patients over the age of 60 are more likely to occur in women. They also note that a significantly higher proportion of the paranoid reactions of old age are coupled with serious defects of vision or hearing. That hearing is a predisposition to paranoid tendencies is known for all ages, but, when coupled with other isolating factors, it undoubtedly strengthens its influence in the development of paranoid thinking. The clinical picture of the aged paranoid is colored by features that are rooted in the insecurity, loneliness, fears, and unfulfilled wishes of old people. Their delusions are more likely to be concerned with property money hostility of

of hearing. When examined, such a patient is found to be, in spite of advanced years, alert, receptive, and shrewd in conversation and quick to seize on any minor inconsistencies and statements the examiner might make. The patient is well oriented and in

good contact with her surroundings. Often there is no deterioration of habits as far as her dress and general appearance is concerned. Outside the scope of her delusions, her judgment and ability to reason may be well preserved. The psychogenic paranoid states are to be differentiated from the senile and arteriosclerotic psychosis. In the senile type the paranoid delusions are vague and loosely connected, and judgments in all spheres are seriously disturbed. Similarly, in arteriosclerotic disease there is obvious evidence of loss of intellectual capacity, but here the paranoid tendencies may show marked fluctuations. Prognostically, the survival rate of a paranoid reaction is vastly better than that for those with senile or arteriosclerotic brain disease. In the latter two diseases, death often terminates the period of hospitalization. However, in the psychogenic paranoid reaction, the patient may survive for long periods of time, but only 20 per cent are discharged from the hospital after a period of 2 years.

Psychophysiological Autonomic and Visceral Disorders

"Psychophysiological disorders" is a term currently used in preference to "psychosomatic disorders." The term "psychosomatic disorders" was abandoned as a diagnostic designation because it was felt to be a point of view held by the medical profession rather than a term which specified the etiology of disease. Psychophysiological reactions represent the physiological expression of an affect (emotion) which is thereby largely prevented from becoming conscious. The symptoms of psychophysiological reactions are therefore due to a chronic and exaggerated state of what would be called ordinarily a normal physiological reaction accompanying an emotion. However, in these circumstances conscious recognition of this emotion has been repressed, but the accompanying physiological response continues and, if prolonged for a sufficient period of time, may lead to structural changes.

PSYCHOPHYSIOLOGICAL SKIN REACTION

That emotional factors influence the condition of the skin is easily recognized. Therefore, there are a group of skin diseases which are believed to be primarily of emotional origin. Pruritis (itching) is a disorder which appears to be more frequent in aging patients. Although it would seem reasonable to attribute itching to senile changes in the skin, it is doubted that this explanation could be accepted without considerable questioning. A number of investigators have noted the relationship of itching to repressed hostility and sexual conflict. Disturbances in the sexual sphere are particularly likely to occur in patients with pruritis vulvae and pruritis anae (Wittkower and Cleghorn, 1954; Weiss and English, 1957).

PSYCHOPHYSIOLOGICAL MUSCULOSKELETALAR REACTION

Arthritis is a very common complaint in elderly people and is perhaps the oldest of

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thritis deformans," resembles an infectious disease and is often referred to as chronic infectious arthritis. This serious illness

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to be related to senescence. This type of arthritis is of the chronic hypertrophic variety and is referred to as osteoarthritis. However, the cause of this illness has not been clearly delineated. Many physicians have observed that the exacerbations in this joint disease can be related to the emotional state of the patient. Irvine noted that intense emotions are related to the onset and persistence of activity of systemic osteoarthritis (Weiss and English, 1957). He investigated fifty cases and noted that severe persistent emotional experience, particularly fear, anxiety, and grief, precipitated the onset of the disease or a progression in the painful arthritis

When the emotional state improved, the arthritis became less painful and progression of bony overgrowth ceased The severity of the emotional disturbance and that of the activity of the arthritis were usually parallel Thus it would appear that the physiological strains produced by prolonged intense emotional reactions have their repercussions in this joint disease of elderly people

Low back pain has probably been a complaint since the dawn of mankind and the assumption of the upright position The low back takes a great deal of strain, and there are many types of physical disorders which can produce this pain However, it also serves as a fixation area for many people with emotional conflicts This increases the treatment problem, and the possibility that a neurotic conflict is producing or contributing to the low back pain must always be given serious consideration

PSYCHOPHYSIOLOGIC GASTROINTESTINAL

A survey of our own clinic indicates that the diagnosis of psychophysiological gastrointestinal reaction is very common in our aging population With the narrowing of interests and the centering of attention upon the basic things in life, such as food elimination of body waste, and general body comfort, it is understandable that elderly patients would become preoccupied with their gastrointestinal tract and exaggerate any symptomatology that may have originally stemmed from an organic disorder

Chronic constipation in young patients is rarely of organic origin and usually can be traced to poor bowel habits or to neurotic conflicts Considerable attention has been given to personality problems found in young patients with chronic constipation, and, since this is a major complaint of elderly patients it is reasonable to wonder if similar psychogenic factors are present in aged patients Busse and his coworkers (1955) found that approximately 25 per cent of well adjusted elderly persons will require laxatives at least two to four times a week Fifty per cent of a large series of subjects over the age of 60 used laxatives either habitually or occasionally Those subjects who required a bowel stimulus were frequently aware of a connection between the onset of constipation and a specific emotional disturbance In women the disturbance was usually related to a difference of opinion between the elderly subject and the daughter in law or son in law Many subjects were aware of the fact that constipation resulted when visiting in the home of an in law, while it would not occur when visiting in homes where they felt very accepted However, when the personality structure of the subjects who were chronically constipated was studied, no consistent personality features could be detected A few showed traits similar to those usually encountered in young adults, and, as would be expected, these patients often have had difficulty for many years It is therefore felt that, although emotional factors do play a role in the bowel disturbances of elderly people, it is probably no greater than that found in younger subjects, and the increased incidence of chronic constipation can in a large measure be attributable to a physiological slowing of peristalsis of the lower bowel

Psychoneurotic Disorders

Psychoneurotic disorders are directly attributable to the existence of anxiety The word "anxiety" can have many connotations and implications and to depart into a detailed scientific discussion of the concept of anxiety at this point is not in accord with the goal of this presentation However, in order to progress in our thinking, it is assumed that anxiety is a basic and fundamental symptom of every type of psychoneurosis The psychological and somatic components of anxiety are similar to those of fear However, anxiety differs from fear in that the object of dread is in part or in total unrecognized by the person

who is experiencing the anxiety Psychologically there is a feeling of impending disaster which is uncomfortable in nature The purpose of fear is to warn an individual that he faces a danger and to mobilize his physiological resources to deal with this danger Anxiety gives the individual a similar sensation or warning that some threat or danger the nature of which is not clearly conscious is present within himself Unfortunately this inner or unconscious danger cannot be dealt with as readily as a realistic threat Overt anxiety is a common psychophysiological state which is experienced by almost everyone Such experiences are usually mild and transient and do not become seriously incapacitating until the anxiety becomes chronic or reaches sufficient intensity so that it impairs working ability and efficiency Therefore a psychoneurosis can be defined as a disturbance in psychic function and behavior It is manifested by anxiety and the defenses against the anxiety as well as the maintenance of the repressed danger The repressed threat (a feeling desire drive or need) cannot be expressed or satisfied in a manner which is acceptable to the individual (superego) and/or to society Obviously the fundamental mechanism in a neurosis is repression and anxiety results when the repressed material is striving to enter consciousness or express itself in some manner The various ways in which the patient attempts to handle this anxiety results in the various types of psychoneurotic reactions

The determination of the incidence of psychoneurotic reactions in any segment of our population is a complex research problem To begin with it is rare to find a patient with a psychoneurosis in which the clinical picture is so clear cut that it fits neatly into a specific diagnostic category In most instances the clinician must content himself with a diagnosis of a mixed psychoneurosis or simply acknowledge that one type of neurotic reaction is the predominant one while secondary symptoms of another psychoneurotic nature are present This more or less kaleidoscopic picture of a psychoneurotic can be somewhat resolved if one recognizes that a core conflict can be present in a personality for many years but that the manifestations of this conflict can vary in response to the life-situation It has been demonstrated on an experimental basis by Philip Seitz (1953) that one psychoneurotic symptom can be substituted for another However it is true that when symptoms are substituted they may be more or less adequate than the previous symptom as a defense against anxiety It is also true that certain symptoms are likely to develop at certain periods of life such as phobias and temper tantrums of childhood the hysterical reactions of the young adult the obsessive compulsive reactions of middle life and the hypochondriacal patterns of the late middle or later years

Clow and Allen (1951) confined their work to a group of psychoneurotics over the age of 60 who required hospitalization because of their complaints The family histories of these patients appeared relatively free of severe mental illness and only 8 per cent of the group had neurotic difficulties of long standing which had interfered with their life adjustment The group showed considerably less preoccupation with sexual matters than is usually encountered in young psychoneurotic patients The most common concern was related to physical complaints which were sometimes reality based but if so were exaggerated An external factor in 75 per cent of the patients was found as the precipitating cause producing severe enough symptoms to require hospitalization Approximately 60 per cent of the group was diagnosed as psychoneurosis mixed type The illness was in most cases characterized by hypochondriasis anxiety and to some degree depression The relationship between hypochondriasis and depression is discussed in another section in this chapter The majority of patients responded to

psychotherapy, and follow up reports indicated that nearly 80 per cent had recovered or were much improved

ANXIETY REACTION

In this type of reaction the anxiety is not restricted to any definite situations or objects, as it is in the case of phobic reactions Since the anxiety permeates widely the thoughts and behavior of the individual, it is often referred to as "diffuse," and, since it is unattached, it is seen as "free floating" The anxious person worries about all sorts of things He is afraid to be alone, and yet he is fearful of being in a group because he will not make a proper impression He seeks outlets for his anxiety, and yet he is constantly insecure and unhappy about any task which he tries to perform Anxiety is not limited to the daytime hours and frequently results in disturbed sleep patterns or nightmares

Attacks of acute anxiety do occur and are often without any apparent precipitating event as recognition of the precipitating event would make it very difficult for the patient to maintain the repression When this occurs in older people they are convinced that they are seriously ill and that they are facing death and they seek hospitalization or considerable medical support The patient literally is in a panic state and feels overwhelmed and completely helpless The somatic component of an acute anxiety attack is manifested by difficulty in breathing often overbreathing, profuse sweating nausea diarrhea, and a feeling that the patient will faint

When anxiety persists for a long period of time the somatic aspects take on increasing importance and the patient can easily shift his concern to his bodily functions This is a clear demonstration of how anxiety which was originally "diffuse" or 'free floating can gradually become crystallized into a hypochondriacal pattern The dynamics and problems of a chronic complainer are discussed under the heading of "Hypochondriasis"

Although tranquilizing drugs are without doubt of value, it is obvious that they are not curative measures, since they do not deal with the problem of a repressed danger and the defenses which are mobilized against the danger Patients who are placed on tranquilizing drugs will improve but when medication is stopped, it is usually just a matter of time before their anxiety re establishes itself Treatment therefore, must be concerned with providing the patient with the support he requires during the extreme periods of the illness and the accessibility for psychotherapy must be determined If the patient can be brought to the point where he can recognize the repressed threat and find a way of dealing with it, this is clearly the best solution When this is not possible, the only avenue of progress lies in rearranging the person's life to avoid stressful stimuli the reinforcement of the particular threat the redirection of energy into rewarding activity, and various supportive techniques

DISSOCIATIVE REACTION, CONVERSION REACTION PHOBIC REACTION, AND OBSESSIVE COMPULSIVE REACTION

These types of psychoneurotic disorders as a rule have their onset prior to middle life To the best of my knowledge, they have no special etiological relationship to the declining years of life, and, although they have considerable psychiatric import, a discussion of the problems is not justified in this chapter

DEPRESSIVE REACTION

As was previously stated, the differentiation between a neurotic and psychotic depressive reaction is often a difficult one and, on occasion, virtually impossible The intensity of the depression, that is, whether neurotic or psychotic, is judged by (*a*) the

extent to which the individual withdraws from reality and is unable to test reality and (*b*) the willingness upon the part of the patient to recognize that he is not wholly responsible for his loss of self esteem and that others are willing to accept him and help him It is recognized that mood changes and actual periods of depression which are more or less incapacitating but do not require hospitalization occur in the lives in the majority of people However it is a recognized fact that depressive periods increase in frequency and depth in the advanced years of life Karl Stern and his co workers (1946 1951) have reported their observations In 1955 Busse and his co workers reported their findings in a study of supposedly well adjusted subjects over the age of 60 They found that a significant portion of the subjects reported a definite increase in frequency and depth of depressive episodes During these episodes the subjects reported that they felt discouraged worried, troubled etc to a degree that they would often feel that there was no reason to live Frequently, they wished that a painless death would intervene and a few entertained suicidal thoughts However in the one group of a hundred aged persons in the lower socioeconomic level, only one admitted a suicidal attempt The depressive periods that were considered statistically in the study occurred at least once a month, and their duration varied from a portion of an hour to a few days The subjects reported that they had not experienced depressive episodes of a similar depth and duration in their younger years These episodes were considered to be truly "reactive" depressions as the subjects were often aware of a precipitating factor, that is, a specific event that would initiate a chain of thoughts which ended in considerable lowering of self esteem Kutner (1956) reports in his community survey on aging that almost one person in eight mentioned protracted depression About one in ten of his sample admitted to frequent preoccupation with death, while not quite 5 per cent of the total has considered committing suicide within the last 5 years His findings regarding suicidal attempts are somewhat higher than that reported by Busse, but the problem of suicide will be discussed later in this section Busse found that there was a difference in the depressive period reported by the groups of subjects separated as to socioeconomic status and continuing employment. In the retired or unemployed group those experiencing depressive episodes varied from 44 to 48 per cent. The frequency dropped to 25 per cent in a series of elderly individuals who were continuing to work Although this would make it appear that working alone plays some vital role in preventing or decreasing the number of depressive episodes, it is possible that there is an underlying difference between those persons in the various groups which permits some persons to continue to work as well as to be relatively immune to depressive episodes Busse (1954), in a previous report dealing with the observations regarding depressive episodes, mentioned that guilt was apparently an unimportant dynamic force in the psychic functioning of so-called normal elderly persons He stated

> Guilt as a psychodynamic force of importance is infrequently seen in our subjects of elderly persons living in the community It appears that old people become involved in
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> gressive impulses which end in self condemnation However the change in the manner of living that is the lack of competition with others appears to foster the development of inferiority feelings which form the basis for depressive episodes The aged person cannot counteract inferiority feelings by demonstrating
>
> the decreasing efficiency of his bodily functions

Following this lead, it was found that the essential mechanism in the depressive epi

sodes of elderly persons is not the turning-inward of unconscious hostile impulses which are unacceptable to the ego This is the common mechanism in the depressions of younger adults Instead, as was described above, the depression is primarily related to the loss of self esteem which is directly related to the aged individual's inability to supply his needs and drives or to defend himself against threats to his security

The fact that the depressive episodes in older people are primarily reactive in type is substantiated by the fact that approximately 85 per cent of subjects living in the community were able to trace the onset of their depressive episodes to some specific stimuli The stimuli were usually related to a suggestion that the subjects might be forced to experience increased physical suffering or lowered financial, professional, or social status Entwined in these depressive episodes is the inevitable change in the body which reduces responsivity, flexibility, and physiological reserve Elderly persons must alter their concept of their body image and are consciously aware of the inability of their bodies readily and defensively to respond to stress Again, it is well to remember that the three influences of biological changes and sociological and psychological alterations are all intermingled in both the cause and manifestations of a depressive episode

Although work or planned creative and recreational activity cannot be considered a panacea for depressions, the fact that there is some relationship between depression and activity cannot be overlooked (Busse *et al*, 1955, Busse, 1956*b*) In the search for various correlations, it is apparent that subjects engaged in adequately planned creative activities fare equally well as those who are continuing to work although past the usual age of retirement. Scrutiny of their previous life patterns reveals that those subjects with adequate planned creative activities had not developed a new pattern of behavior, since they had participated in such activities for many years Although work and creative activity defenses are useful against depressive episodes, they do not guarantee that the subject will not suffer such emotional experiences, as there are some individuals who, in spite of an apparently good social adjustment, are victims of periods of depression A negative correlation is found with excessive verbalized type of hypochondriasis Patients who are chronic complainers invariably suffer from depressive episodes The entire problem of hypochondriases will be discussed under the proper section

SUICIDE IN OLD AGE

It could be stated with some correctness that a discussion of suicide would be more appropriate in the discussion of psychotic depressions However, according to current definitions, individuals who attempt or succeed in suicidal attempts are in many instances not psychotic Unfortunately, there is a special relationship between old age and suicide In those countries of the world in which adequate figures are available and when such suicidal rates are standardized for age, there is a peak in late middle or old age Why this should be true is debatable, but plausible theories can be advanced Gruhle (1941) reported that psychosis in old age was rarely a cause of suicide He expressed a belief that social and psychological factors are mainly responsible He includes in this awareness of physical and mental decline, loneliness, forced idleness, inability to adapt to changes in the conditions of life, and, last, incurable disease It is important to note that Gruhle's dynamics regarding suicide are very similar to those put forth by Busse as causes for depressions in elderly people However, Gruhle's studies may shed some light on why certain old persons will commit suicide rather than tolerate the depression His work indicates that a suicide is related not only to the depressive episode but to a lifelong history of hardships In this light it is understandable that the toleration for hard

ship has declined to a point where the individual terminates his existence

There are many other factors which must be examined when considering suicidal rates For instance suicidal rates are higher in urban than in cultural areas lower in Catholic than in Protestant countries higher in the unmarried as opposed to the married increased in times of unemployment and economic depression decreasd during war and reach a peak in the early summer In England there is a differential peak for men and women (Mayer Gross *et al* 1955 p 503) Men have the highest rate in the years 65 and over while for English women the peak occurs between the ages of 45 64 It is conceivable that in women the peak is related to the menopause or to the changes in family relations which take place at this time While in men who face retirement at 65 or thereafter the major change in their lives come about at this time

Suicide in old age cannot be attributed to any single factor such as a particular mental illness either organic or functional or to any specific socioeconomic stress

V Common Symptoms Associated with Aging

Hypochondriasis

Hypochondriasis is not a disease entity Therefore it is not listed as a diagnostic category in the *Diagnostic and Statistical Manual* (American Psychiatric Association 1954) Hypochondriasis is a syndrome consisting of an anxious preoccupation with the body or a portion of the body which the patient believes is either diseased or not functioning properly This syndrome may be associated with a variety of medical conditions and may be a manifestation of a neurosis a psychosis a psychophysiological reaction or a personality disturbance In our study of an adult population of a clinic hypochondriasis was found to be more prevalent in elderly patients (Busse, 1954, Busse *et al*, 1956) This conclusion has been expressed by other investigators who report a high incidence of hypochondriasis in psychiatric patients during the declining years of life (Walters 1940 Woltman 1942) For a number of years my colleagues and I devoted considerable effort to studying and treating patients with hypochondriasis Such patients were gathered together in a special clinic A survey of the patients in attendance in this special clinic revealed that better than half were over the age of 60 and that the majority were females Our efforts resulted in the development of an effective therapeutic approach which will be outlined later in this discussion

The persistent or chronic complainer is a time-consuming and frustrating medical problem and its adverse social influences are very well known to any person who has been forced to listen to the repetitive and detailed account of imaginary or exaggerated illnesses However if we are to understand this syndrome we must also take into consideration the social and cultural setting in which the chronic complainer develops In most Western cultures great emphasis is placed upon the maintenance of personal independence and the ability to achieve Most people judge the worth of others by material and financial success and advancement of social status. Our society indicates little acceptance for the non achiever or the financial failure On the other hand our Christian beliefs and democratic ideals give the person who is physically ill the right to medical care and financial assistance through a church welfare or governmental agency paternal groups labor organizations or places of employment When a person fails or feels he is failing he becomes fearful that he will be condemned by society and labeled a lazy or incompetent person Few persons can admit to themselves or others the true cause of a failure One method for a person to maintain self respect is to become sick and then he can say with conviction and a minimum of guilt, It is not my fault I am not a success, I am sick, and, there-

fore my failures are justifiably excused Chronic complaining as a defense may be successful for a varying period of time but eventually his family and business associates recognize that there is a discrepancy between his complaints his appearance and his physical capacity to do the things that he wants to do Recognition that the excuse of illness is physically unjustified makes people feel that they are being exploited Society s indignation is added to by unconscious resentment which stems from the fact that most people at times during their life play sick to avoid trouble but their conscience will not permit them to employ this defense to the same degree that it is used by the chronic complainer The censoring of their own conscience adds to the total resentment directed against the chronic complainer Consequently the hypochondriac s adjustment problem becomes greater when his friends and relatives discover his secret Under any circumstances the hypochondriac is difficult to live with but it seems even harder when the chronic complainer is an older person This is because the younger people who feel some affection and responsibility for the chronic complainer are caught with feelings of annoyance rejection and guilt which become interwoven with their concern over possibly neglecting the older person

An understanding of the psychological mechanisms which underly the appearance of hypochondriasis is most helpful in the approach to this problem There are three major components in the psychodynamics of hypochondriasis (1) there may be a shift away or a withdrawal of the patient s interests from other persons or objects around him and a centering of his psychic interests upon himself his body and its functioning (2) the restrictions and discomfort produced by this illness may be utilized by the patient as punishment and partial atonement for guilt resulting from hostile vengeful feelings against the people who are quite close to him and (3) the syndrome can be caused by a shift of anxiety from some specific psychic area to a less threatening concern with bodily disease and functioning If we keep in mind these psychodynamics and apply them to elderly people in their particular socioeconomic situation the disease is understandable and a treatment program can be meaningfully and rewardingly applied Certainly the retired older worker who has had no other interest except his work is a likely subject for the development of hypochondriasis utilizing the first mechanism *Suddenly deprived of an outlet* for his energy and interest he is likely to focus his attention upon himself He becomes aware of bodily functions which he ignored in the past and may give them just as much attention as he gave to his work before retirement The second mechanism the use of the symptom as a means of self punishment to dispel guilt feelings is not as frequent in the elderly as it is in younger people This may be related to my belief that elderly people in contrast to younger people are much more likely to turn their hostile feelings outward than inward The rarity of this particular mechanism in the older age group was shown clearly in the special clinic designed to deal with hypochondriacs The last mechanism the shift of anxiety from some specific area of psychic conflict to bodily functioning is certainly encountered in elderly people and is *related to their anxiety over loss of social* prestige or financial security This type of chronic complainer refuses to admit that club members have relegated him to an unimportant position He denies that he is concerned about this loss of prestige but insists that he is more worried about some illness or weakness of his body

Over the years we have continued to feel dissatisfied regarding our knowledge of the etiology and dynamics of hypochondriasis Pursuit of this interest has forced us to the recognition that the term hypochondriac is a label attached to those individuals who verbally or behaviorally express overconcern with their health in an attempt to defend against anxiety and solicit the sympathy forgiveness, and help of others In

addition, they will not appear in a medical statistic unless they have repeatedly sought medical help With this in mind, in our study of community volunteers, we shifted our research approach and developed the concept of high bodily concern The concept of ' high bodily concern does not imply any implication regarding the etiology of the concern The concern may be reality determined, that is consistent with the presence of organic disease, or it may be attributable to a neurotic origin This permitted us to study a series of subjects with high bodily concern and compare them to a control group matched for age sex and race as well as socioeconomic status From this study we concluded that in a sample of so-called normal community subjects over the age of 60, approximately 30 per cent had ' high ' bodily concern one half of this group were primarily of psychological origin, and at least another one fourth of these subjects had a neurotic overlay (Busse *et al*, 1956) In addition, 74 per cent of the hypochondriacs show other neurotic symptoms but have no higher incidence of psychophysiological reaction than the controlled group This study indicated that there was a fundamental difference between the majority of hypochondriacs in the community group and the hypochondriac that is encountered in the clinic This difference is that those in our community group utilized this syndrome as a social crutch but generally avoided seeking medical help

Additional information regarding the possible factors in hypochondriasis have been contributed by the study *Five Hundred over Sixty* (Kutner *et al*, 1956) This study also reports that social isolation is associated with relatively poor health In pursuing the older person's concern about his health, Kutner points out that it might be assumed that a person who leads a busy social life, seeing family and friends frequently, would tend to be less preoccupied with his health Isolation would give him the time and energy to devote to self-observation and therefore to develop a high bodily concern In pursuing this, these investigators pose the question, "What influence does social isolation play in concern with health among those good and poor in health? ' Paradoxically, it was found that, among those in good health based upon self ratings, there are significantly fewer worriers in the relatively social isolated group than in the non isolated group In

group It therefore, seems that having friends and relatives in close contact with elderly individuals tends to raise their level of concern about health Whether this is a virtue or a vice is difficult to determine, as a certain amount of health awareness is essential to maintain good health and it is doubtful if one can consider Kutner s subjects hypochondriacal in the accepted understanding of the designation by the medical profession This question is really not settled by the fact that Kutner *et al* (1956 p 171) found that those who have concern about their health status, whether they are in good or poor health, tend to become more active in their efforts to check the status of their health through the use of health facilities Recognizing this problem the same investigators attempted to solve this by developing a neurotic symptoms index and correlating the index with the actual health status and the use of medical facilities Unfortunately, the neurotic symptoms index is limited to three symptoms nervousness, headaches and insomnia The limitations imposed by this index are recognized by these investigators, but there is another deficiency which deserves attention inasmuch as the health status apparently was determined by each subject by supplying a medical history and self evaluation This possible defect in the study may play a role in the fact that the symptoms included in the neurotic index are ' heavily displayed among those in poor health and much less so among those in good health " However, of considerable importance is their finding that, when health

is good and as neurotic symptoms increase, use of medical resources *decreases* significantly It, therefore, would appear that these investigators encountered considerable difficulty in clearly separating out a group which could be looked upon as hypo chondriacs

The treatment program for a chronic complainer should include (1) redirection of interests into emotionally stimulating and rewarding areas and (2) an opportunity to recognize specific anxieties and to solve them rather than shifting them to bodily compaints In order to accomplish this, certain therapeutic principles are recommended For details regarding the rationale and application of these principles, the reader is referred to the pertinent pub lications (Busse, 1954, 1956*a*, 1956*b*) In summary, the first principle to which the physician should adhere is *not* confronting the patient with the fact that there is insufficient organic evidence to support his complaint and that his difficulty is primarily of emotional origin To confront a pa tient with this fact strips him of his defense and increases anxiety and mobilizes his hostility The second principle is that the physician should *not* tell the patient's child, spouse, or friends that this preoccu pation with self is of emotional origin, since the relative will inevitably become intoler ant and confront the patient with this knowledge When this happens, the patient feels that he has been betrayed by his friend, the physician Third, to help the patient, the physician must be willing to ac cept his complaints, be willing to show an interest in their possible origin, but refrain from giving the patient a specific diagno sis or explanation Rather he should try supportive techniques including medica tion or placebos, which will be concrete evidence that the patient is receiving help from the physician Finally the physician should be willing to talk with the patient, explore possible emotional interests with him, and encourage him to find new sources of satisfaction These principles can achieve their maximum value only if they are based upon the understanding and application of specific techniques (Busse, 1954, 1956)

INSOMNIA

Sleep is obviously nature's way of providing a period during which the body can rest and recuperate Unfortunately, sleep not only serves a physiological function but provides for many persons a period of escape from the many stresses of life When sleep does not come for these individuals to provide them with the sought for escape, they become anxious, and their life is further complicated Chronic insomnia can be rarely attributed to an organic problem but is usually traceable to an unsolved emotional conflict involving feelings of guilt and hostility with fear of retaliation

The amount of sleep required by each individual varies widely Some people can get along on 5–6 hours a night, while others will require a minimum of 8 That insecurity and unfamiliar surroundings contribute to poor sleep is reported by most people who have difficulty going to sleep in a different bed, in a Pullman car, or in a hospital However, this situational lack of sleep is quite different from chronic insom nia Of course, sleeplessness is sometimes caused by pain and, under such circumstances, it is understandable that sedation is required However, ordinarily chronic sleeplessness will not really be helped by merely employing sleep inducing drugs, one must rather approach the problem with an aim to discovering the cause of anxiety

The question of sleep requirement of elderly subjects required careful thought A fair number of elderly subjects report that they require less sleep now than they had when they were younger However, if their daily pattern of life is carefully reviewed, one finds that they frequently take short periods of rest during the day and that they do not exert themselves to the extent that they did in the past It is understandable that the amount of rest required at night has declined

Busse *et al* (1955) found that, in a

group of subjects over the age of 60, 7–10 per cent of these persons used sleeping pills habitually In various groups of apparently well adjusted community subjects over the age of 60 20–40 per cent of each series occasionally used sleeping pills In elderly subjects who are free of physical pain those who use sleeping pills excessively are found to have many other neurotic complaints and are poorly adjusted in society

Ginzberg (1955) in a study of sleep disturbances in hospitalized and county home residents found that age and organic brain disease did not significantly contribute to insomnia However in the non psychotic elderly county home residents 18 6 per cent complained of insomnia This incidence of insomnia was the lowest on a list of ten complaints which included joint pain fatigue decreased vision and hearing etc

Kutner and his co-workers (1956 p 131) in their study *Five Hundred over Sixty* reported that 50 per cent complained (not measured) of chronic insomnia Nearly one fourth of this group usually awake tired and exhausted I have some doubt as to the value of this observation since a higher percentage of medical students have the same feeling upon awaking

NOCTURNAL RESTLESSNESS

It is common for a physician to be called at night because an older person is disturbing others in his household by wandering aimlessly around the house somewhat confused anxious and resistant to any suggestion that he go to bed and try to get some sleep This pattern is primarily found in older people with decreased vision and hearing who also show evidence of mental deterioration Perception is extremely important in the maintenance of orientation and psychophysiological balance (Ramsdell 1947) At night with darkness and quiet the further reduction of these orienting stimuli make the patient anxious and confused The patient feels increasingly threatened and becomes unco operative Homes for the aged have found that adequate lighting and a reasonable amount of activity do much to reduce nocturnal restlessness

WANDERING

Another specific problem is the wanderlust that is often found in old people The children of elderly parents complain that father or mother is really incapable of driving an automobile and should not be permitted to have an automobile or driver's license Yet they have both, and in addition they refuse to admit that their driving skill has decreased The children frequently do not know where grandfather has gone for the afternoon and if he is late in coming home they worry that he may have gotten into some difficulty Another form that this wanderlust takes is just walking or wandering around the neighborhood In many ways this wanderlust is analogous to the normal urge for travel Most of us enjoy an opportunity to get away from problems and at the same time experience new excitement which we can relive again in reporting our travels to someone else When the wanderlust appears in an old person it indicates that certain things have not been adequately supplied to him He feels that he has no significant role in his home environment and that he is not getting the new experiences in that setting that he requires The person wandering about does not really know what he is looking for but feels that he must do something to reduce tension even though little will be accomplished by walking or driving around Clinical experience has convincingly demonstrated that an older person who tends to wander in a detached fashion can be changed by simply making things interesting exciting and somewhat demanding in his home environment To produce such a home environment requires effort upon the part of his family but it is better to develop preventive measures than to deal with the unfortunate consequences that can result from injury to himself or others or if the wandering continues unchecked

IRRITABILITY AND HOSTILITY

Irritability, the forerunner of overt outbreaks of anger, is evidence that the patient is experiencing tension for which he cannot find suitable relief In elderly persons this symptom often appears when the person realizes that his physical functions are declining and that he is not as strong, controlled, and as effective as he once was If the persons in the environment of an elderly person accept his decline in physical function without rejecting him, it is much easier for the person himself to accept these changes The specific recommendations for handling this type of problem can be found in the appropriate references (Busse, 1956, Busse and Nichols 1958)

VI Summary

The mental health of the aged is believed of primary importance, because any improvement in the socioeconomic situation or the physical health of a person is of little value to the individual unless he is mentally capable of appreciating it and utilizing it satisfactorily

The psychopathology of the elderly patient has unique and common features which distinguishes it from the psychic disturbance of young or middle-aged adults The mental disorders of particular importance in the later years of life have been reviewed with particular emphasis upon symptoms etiology, and pathology Treatment has not been presented in detail Adequately to present the various therapeutic approaches and the rationale of such treatments would require a lengthy presentation which would not be in keeping with the intent of this chapter It is also evident that the new and rapidly improving treatment methods would quickly render such a presentation obsolete

The diseases which are discussed are presented in the sequence which is found in the *Diagnostic and Statistical Manual of Mental Disorders* prepared by the American Psychiatric Association (1954) and which is the standard diagnostic nomenclature utilized by the medical profession

The organic brain disorders are a serious medical and socioeconomic problem, but the psychogenic reactions of the aged are believed to be equally important and should be more promptly recognized, understood, and alleviated The concept of multiple etiology of mental disorders, both so called organic reactions and psychogenic reactions, is believed to be necessary to comprehend the particular skills that are required and the magnitude of the resources which are needed to achieve a better level of mental health for the aged population

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stature, it is impossible to attribute the obtained differences between the two groups to an age decline in stature alone Trotter and Gleser were able to eliminate these possible differences in maximum stature in their sample by using the length of the long bones to estimate the probable stature of the individual at age 30

To solve this problem, these investigators obtained measurements from 855 cadavers (615 male and 240 female) ranging in age from 19 to 91 years Actual skeletal measurements of the femur, tibia, and humerus were made In addition to the pre-

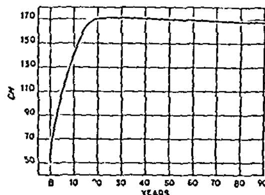


Fig 1—Hypothetical average stature curve from birth to 90 years of age (After Trotter and Gleser 1951)

cise estimate of the decline in stature mentioned above, these investigators conclude that (1) a partial correlation of approximately —25 is found between age and stature and that (2) the regression of stature upon age is linear From these data the hypothetical "developmental" curve of stature shown in Figure 1 was constructed

The decline in stature in old age is thought to be largely the result of changes in the spine (flattening of the intervertebral cartilages and perhaps of the vertebral bodies themselves, resulting in curvature of the spine), of inability to maintain an erect posture through failure to exert the required muscular effort of the extensor muscles of the knees and hips, resulting in the familiar bent knee gait of the aged, and, finally, of a general thinning of all weight bearing cartilages (Hooton, 1947) Since these changes do not affect the length of the long bones, which correlate highly with stature, secular changes in stature in successive generations would be reflected in long bone length By utilization of the length of the long bones, Trotter and Gleser (1951) were able to determine whether successive age groups in the sample were or were not of equal heights at maturity regardless of the postmature age at which measurements were taken Thus the significant decline in the stature which still obtains after differences in long bone lengths have been removed or held constant statistically can be attributed to age

SURVEY DATA

Various cross sectional surveys tend to substantiate the findings of Trotter and Gleser (1951), irregularities in trend, however, are found (Kemsley, 1950, Hooton and Dupertius, 1951, Clements and Pickett 1954*a*, 1954*b*)

Kemsley's data (1950), for example, show that, of a sample of about 27,500 British males measured in 1943, the 21 5 year age group was the tallest, with a mean height of 67 34 inches From this age onward there is a steady decline in stature, reaching a low of 63 83 inches for the age group 74 5 years and above There are, however, only sixteen cases in the latter group (see Table 1)

If the Trotter and Gleser decline constant is applied to these data, using 21 5 rather than 30 years as the year of origin, we should expect a mean height of 66 09 inches at age 74 5 Since this is considerably above the obtained height, it is obvious that factors other than those upon which the Trotter Gleser constant depend enter into rate of decline in this series

In the same study data were gathered on about 33,500 women aged 14 and above For these a maximum stature of 62 42 inches was reached by the 20 5 year group The 74 5 year and older group obtained a

mean height of only 60 0 inches, although we should expect on the basis of the Trotter Gleser constant a mean height of 61 14 inches for this group

Hooton and Dupertuis (1951) present data on stature obtained on a sample of 9957 Irish males in which the maximum height (173 2 cm or 68 2 inches) is some average stature of the 70–74 year subgroup is 167 8 cm, or 5 4 cm less than maximum height Hooton feels that this decline in stature is not too great to be attributed to bent posture and age shrinkage rather than to selective factors When one considers that the Trotter Gleser constant applies to age shrinkage alone, it is proba

TABLE 1*

AVERAGE MEASUREMENTS OF A POPULATION BY AGE AND SEX
(N = 27 515 Males and 33 562 Females)

Age	Height (Inches)†		Weight‡		Weight Adjusted For Height	
	Males	Females	Males	Females	66-Inch Males	62 Inch Females
14	61 10	60 77	94 3	99 6	113 9	103 8
14 5	62 43	61 35	101 1	105 2	115 4	107 4
15 5	64 51	62 03	111 7	110 0	117 7	109 9
16 5	65 92	62 14	120 0	112 8	120 3	112 3
17 5	66 31	62 16	124 5	114 4	123 3	113 9
18 5	66 74	62 30	127 8	116 0	124 8	115 0
19 5	66 94	62 26	131 2	115 7	127 4	114 8
20 5	66 92	62 42	131 6	118 0	127 9	116 6
21 5	67 34	62 41	136 0	117 3	130 6	115 9
22 5	67 04	62 35	135 0	117 7	130 8	116 5
23 5	66 83	62 26	135 3	117 0	132 0	116 1
24 5 29 5	66 76	62 12	134 3	117 3	133 6	116 9
29 5–34 5	66 73	61 99	138 4	119 6	135 8	119 6
34 5–39 5	66 64	61 87	139 0	122 3	136 7	122 7
39 5–44 5	66 09	61 60	137 2	125 8	136 9	127 0
44 5–49 5	65 89	61 48	137 2	128 3	137 6	129 9
49 5 54 5	65 69	61 24	137 2	130 2	138 3	132 5
54 5 59 5	65 55	60 96	137 5	129 8	139 1	132 9
59 5–64 5	65 07	60 66	136 8	127 1	140 2	131 1
64 5–69 5§	64 67	60 38	136 4	123 1	141 2	128 0
69 5 74 5	64 64	59 96	136 0	118 9	140 9	125 0
74 5 and over‖	63 83	60 00	125 4	117 8	133 2	123 8
All ages	66 02	61 92	132 3	119 5	132 2	119 7

* Source Kemsley (1950) Table 1 p 163
† Es imated height w thout shoes
‡ Estimated nude weight
§ Fewer than 100 females n th s interval
‖ Fewer than 50 males and 50 females n th s age nterval

what greater than the Kemsley population and is reached at a later age (30–39 years) At this point diminution begins and progresses steadily through successive age groups at a rate in excess of that which would be expected on the basis of the Trotter Gleser constant Thus, if we assume that maximum height were reached at age 30, we should expect a mean decline in height of 2 4 cm at age 70 Actually, the ble that bent posture accounts for at least half the observed shrinkage in this population

The conjecture might be raised that the age decline in stature shown in the above studies could result in some way from sampling errors However, in Figure 2 the familiar regression in stature is shown in a representative sample of the entire Canadian population of 15,000,000 In this

study 22,000 persons (400 in each age and sex group) from every region of the country were measured by field workers during 1953 Heights and weights were recorded with subjects wearing ordinary street dress but without shoes Note that maximum stature was reached by men at age 25–29 years (68 3 inches) and by women at age 20–24 (62 8 inches) Again the decline in stature from age at maximum height to age 65 and over is greater than would be expected on the basis of the Trotter Gleser constant

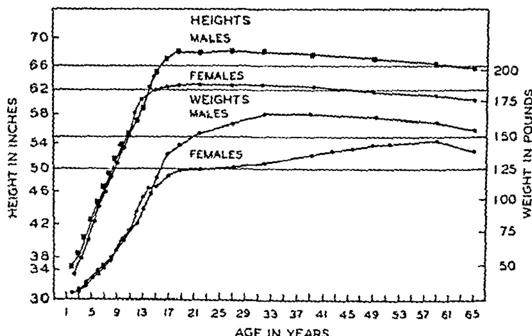


FIG 2 —Mean height and weight by age and sex of a representative sample of the entire Canadian population in 1953 Note earlier maturity of girls as indicated by greater height and weight of girls early in second decade Men s average weight decreases after age 30 while average of women continues upward into late fifties (After Pett, 1955, Fig 1 p 865)

Curiously Holmgren (1952) reports evidence of continued growth in stature until age 70 for men and 50 for women The data for this unusual conclusion are derived from measurements of 46,000 hospital outpatients in Sweden during the period 1914–30 Although his successive annual samples show the expected age height relationship, Holmgren deduces from the obtained yearly height increases of his material at all ages that growth in stature must contribute at least in part to the observed increments Indeed, his samples do show in terms of the year of birth of his subjects continuous height increases since the middle of the nineteenth century However, since different individuals comprise the yearly samples and since the samples are representative only of the hospital outpatients during the period of study, it is difficult to accept Holmgren's conclusions concerning continued growth in stature during maturity without corroboration from longitudinal data

WEIGHT

The psychological effects of decline in height are undoubtedly of considerably less importance to the individual than are the seemingly inevitable changes in weight which come with the years of postmaturity Indeed, few people are aware of any dimi

nution in stature in later life, although very old people who were particularly conscious of their youthful height may experience some feeling of regret over a slight loss in physical stature For example, an 82 year old man who claimed to have been 6 feet 4 inches tall as a young man, although he stood no more than 6 feet 1 inch at his present age, was fond of telling people how tall he had been Such feelings of regret over these small diminutions in stature are rare Not so is the expressed concern over weight changes

Unlike stature, weight continues to increase well beyond the twenties and thirties Since this increase is one of size alone and is not at all likely to increase the functional or social capacity of the individual it is largely regarded as yet another unfavorable age sign The Kemsley data, cited above, showed that women in the sample increased in weight until the 49 5–54 5 year quinquinium, and, when these measurements were corrected for height, the period of increase was extended to the age interval 54 5–59 5, at which time an estimated mean weight of 132 9 pounds was reached (see Table 1) The men in this population do not show the continued increases in weight after the age interval 34 5 39 5 however, in the measurements adjusted for height, small increments are seen until the late sixties

As would be expected from the stature data presented above the sample of Irish males studied by Hooton and Dupertius (1951) is heavier than the Kemsley group, although much the same pattern of weight increase is seen Although a maximum weight of 164 6 pounds (157 6 pounds estimated nude weight) is attained in the 55–59 year group it is only 2 pounds greater than the weights of the 30–35 year group Oscillations occur in the means of the intervening groups Hooton concludes that the shrinkage after the 30–59 year plateau results from the aging process but recognizes that the differential survival of lighter men may be a contributing factor

WEIGHT, BODY COMPOSITION, AND BODY STRUCTURE

Continued increments in body weight after the cessation of growth in stature lead to changes both in body composition and in body structure The former changes are of greatest significance to health and function, while the latter become most apparent in the changed appearance of the body Indeed, one of the earliest signs of aging is given by the increase in body weight accompanied by noticeable increases in various girth measurements

LOCUS OF FAT DEPOSITION

The subcutaneous fat layer has particular psychological significance, because in large measure the appearance of the individual is determined by its amount and distribution As we have already seen demonstrated empirically, total body weight continues to increase well into the middle years of life, particularly in women This total weight can be accounted for in terms of the separate weights of the basic body components—blood, interstitial fluid, bone, fat and active tissues (Brozek and Keys, 1951) As total weight increases with age, however, the relative proportion of these basic components change, and this change is very marked in the case of fat containing tissue Thus Brozek and Keys (1950) have shown that fatty tissue accounted for 9 8 per cent of the body weight of a group of young men (mean age 22 1 years) and for 21 0 per cent of the weight of an older group (mean age 49 1 years), even though the relative body weights of the two groups were the same

Several studies have described age changes in this fat layer or tela adiposa Two principal techniques have been used in these investigations (1) the X ray and roentgenogram and (2) the skin fold methods In the former method the amount of subcutaneous fat is determined by measurement of the fat plus skin shadow on soft tissue X rays (Garn, 1957*a*), while in the latter this estimation is made by meas-

uring with calipers the thickness of a fold of skin as it is held between the fingers Although the X ray method is considered to be more precise, the extensive equipment needed limits its use to the labora tory The pinch caliper method does not suffer from this particular disadvantage Fortunately, the relationship between measurements obtained by the two methods is sufficiently high ($r = 88$) to allow com parisons between results of studies using both methods (Garn, 1956 Garn and Gor man, 1956)

The subcutaneous adipose tissue may be thought of as a continuous layer of fat, connective tissue, blood vessels, and water covering the entire surface of the body just under the skin The thickness of this layer is not uniform but rather is markedly thicker over some parts of the body than others With increasing age and weight, fat deposition occurs at different rates for various body areas Almost without exception the fat layer thickens at a rate which is considerably greater for the trunk than for the extremities For example, Garn and Harper (1955) in a roentgenographic study of 85 white males from 20 to 69 years of age showed a marked tendency for fat to be deposited in relatively greater quantities over the pelvic region as age in creases than on distal parts of the arms and legs Thus arm and leg fat, thinner to begin with, showed considerably less absolute and percentage gain than did iliac (hip) fat Of the nine body sites measured, only one, anterior leg fat, failed to show a significant positive correlation ratio with age Garn and Harper conclude that the gain in both weight and subcutaneous fat occurs early in males and is largely com pleted by age 40

SEX DIFFERENCES IN FATTENING

Skerlj (1954) reports the age associated increase in relative skin fold thickness for the total trunk area to be three times greater in males than in females in a sam ple covering a wide range of ages Relative skin fold thickness apparently refers to the percentage contribution of the skin fold thickness of a particular part of the body to the summation of all measurements from various sites (Garn and Young, 1956) What Skerlj is saying, therefore, is that the trunk, with increasing age, accounts for a greater and greater percentage of total surface fat and that this percentage increase occurs at a faster rate in men than in women In the neck area alone the increase for males is eleven times greater than for females This differential thicken ing of the surface fat layer is apparently quite intensive and regular in males but not so in females Thus skin fold thickness for the entire trunk is greater in prepu bertal than in pubertal girls and that of parous women is below that of nulliparous. Even menopausal women are considerably below adult men in this respect, and both parous and nulliparous women are below pubertal boys

The above relationships must not be confused with the sex differences in ab solute amounts of subcutaneous fat Here, generally speaking, the adipose layer is actually thicker in women than in men Garn (1957*b*) reports that in seven out of nine body sites measured (arm, leg, and pelvic regions) median subcutaneous fat thicknesses were between 41 and 89 per cent greater in adult females than in males In the remaining two regions (iliac crest and deltoid pocket) the thicknesses were practically identical He summarizes his findings succinctly by saying, "Women car ry more fat on and less in their smaller frames"

Sex differences in the composition of the adult leg have also been studied Garn and Saalberg (1953) report, in an investigation based upon the roentgenograms of 50 men and 50 women between the ages of 20 and 50 years that the female leg has a lower absolute muscle content, higher absolute and percentage fat content, but only a negligible difference in diameter Age changes in leg composition were reported to be insignificant in men, but in women

leg fat increased markedly with age, especially medial leg fat Curiously, fat distribution on the four quadrants of the lower leg do not exhibit the same age related changes, for anterior leg fat in both men and women actually decreases in thickness from midway in the second decade until about age 30 (Garn and Young, 1956) Reynolds and Asakawa (1950) also report sex differences in tissue composition of the leg, and they were able to devise a fat to bone index which differentiated the men from women in the sample successfully nine out of ten times

FAT DEPOSITION AND LIFE EXPECTANCY

Both Skerlj (1954) and Garn and Saalberg (1953) speculate upon a possible relationship between sex differences in fat content and the fact of greater female life-expectancy Curiously, the direction of their speculations are quite different Garn and Saalberg state that at all age levels woman is more obese than man and that during middle age she accumulates fat more rapidly Because of woman s greater life expectancy they feel that some modification is necessary in the generally assumed causal relationship between obesity and high mortality rate

Skerlj (1954), on the other hand, states that ' one is challenged to connect these great changes [increases] in the distribution of soft tissues in males with a life expectancy which is below that of females ' Since the fact of greater female obesity cannot be disputed Skerlj is apparently drawing attention to the tendency in males to increase in amount of subcutaneous adipose tissue on the trunk at a faster rate than females even though trunk fat thickness in the male does not exceed that of females (Garn, 1957) These are of course, highly speculative questions which cannot be answered until we have many more facts than are now available

We do, however, have a reasonably clear picture about age related weight changes in the body Total body weight continues to increase after the cessation of growth in stature well into the sixth and seventh decades, after which the mean weights of successive age groups decrease We do not know whether this turning point represents a maximum in the curve of development or whether it is a result of selective survival of lighter weighted individuals Indeed, it may well reflect the common result of both causes We also know that this increase is almost entirely the result of the accumulation of fatty tissue, probably accompanied by some diminution of other tissues, notably muscle In addition, we can conclude that changes do occur in fat deposition with age and that sex differences exist in this respect

AGE VARIATIONS IN BODY FORM

Perhaps in terms of personal satisfaction with body appearance, the weight increases occurring during the middle years of life are fully as significant as the involutional changes of stature and weight of the senium Certainly, the altering body configuration becomes apparent as changes in the various girth measurements force themselves upon the attention of the individual and impose an obvious psychological threat Basically, the structural changes of the body result from changes in tissue composition plus the mechanical effects of use and wear, with the most noticeable effects being produced by changing amounts and distribution of the soft subcutaneous tissues This has already been discussed in previous sections with reference to age changes in the deposition of fatty tissues More can be said here with specific reference to gross configurational changes in the body

Descriptions of body form have been attempted by several investigators with varying degrees of success While no completely satisfactory system has as yet been devised, some conceptual and methodological explorations have been undertaken in this area, with results that have some interesting geronotologic implications Since

appearance is so dependent upon subcutaneous fat distribution, attempts have been made at constructing systems of classifying patterns of fat distribution as descriptions of total body configuration Both Skerlj and Garn have devised such systems and have made use of them, at least in a preliminary way, in describing age changes in adult body form Their methods are, however, quite different, with the Skerlj system being somewhat impressionistic and with Garn using a more statistical approach In the final analysis both methods depend upon the investigator's judgment in the former the classification of body form is made from direct observation of the subject, while in the latter the judgment is of the statistical profile derived from body measurements

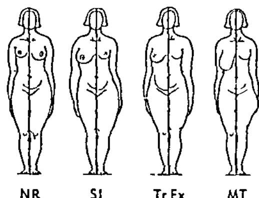


FIG 3 —Pictorial representation of the extremes (types) of body form with reference to the amount and distribution of soft tissue (*N* normal *R*, Rubens, *S*, superior, *I*, inferior, *Tr* truncic, *Ex* extremital, *M*, mammary, *T*, trochanteric) (After Skerlj *et al*, 1953)

VECTOR ANALYSIS

A most graphic exposition of age change in body form is given in the investigation by Skerlj *et al* (1953), who studied a series of 84 women volunteers ranging in age from 18 to 67 years While this population cannot be considered with certainty as being representative of women in general, there is no evident selective bias in terms of the major variable—body weight. An age analysis of this group was made in terms of Skerlj's system of classification by which the female body form may be described in terms of certain qualitative vectors These vectors characterize variation in body form in terms of the "dominant localization of massive body structures, particularly adipose tissue" The presence or absence of a well defined vector is indicated by the investigator without attempt at precise measurement The vectors are as follows

Vector I

- L—harmonious deficiency of fat which extends through, and in this study is combined with,
- N—moderate to abundant, harmonious distribution of fat through
- R—harmonious obesity reminiscent of the paintings of Rubens, referred to as adipose or Rubens extreme

Vector II

- S—preponderance of obesity occuring above the waist (superior) continuing through
- I—localization of adipose tissue in hips and extremities (inferior)

Vector III

- Tr—obesity localized in the trunk (truncic), varying through
- Ex—localization of fat in limbs but not in trunk (extremital)

Additional vectors

- M—large fat deposits in breasts (mammary)
- T—large fat deposits over greater trochanters of the femora (trochanteric)
- Pst—localization of fat in buttocks (pseudosteatopygous)

Illustrations of all but the first and last of these types are given in Figure 3, while the percentage frequencies of these vectors in the sample are given in Table 2 Since each individual may represent more than one vector, the columns in this table add up to more than 100 per cent.

The investigators point first to the decline in one vector "types" (Table 2) as supporting the suggestion that, with the increase in soft tissue occurring with age,

there is a tendency for it to become less harmonious in distribution The decrease in N percentages and the increase in R, Tr, T and M indicate a tendency for older women to gain in the soft tissues of the trunk and for the younger women to be relatively greater sized in the legs In the older women also more conspicuous fat deposits are located in the breasts and in the trochanteric regions Citing other evidence, the investigators point out that on a sample of 100 young men of college age and 300 middle aged men much the same vector differences as those found in women were obtained resulting in increasing typological similarity between the sexes as age advances The similarity carries over even to the development of an M vector in the male

In other parts of this study quantitative estimates of the total body fat and subcutaneous fat were obtained The former estimate is based upon the specific gravity of the body obtained by weighing the individual under water while the latter was obtained from the measurement of skin fold thickness on ten parts of the body From these measurements it was possible to determine the contribution of subcutaneous fat to total body fat as well as the relationship between body weight and body fat It is apparent from the data that even though total weight ceases to increase in later middle age increments in body fat do occur Furthermore these increments occur in inner rather than in subcutaneous fat. Since there is no increase in total weight the accumulation to inner fat must result from the fatty infiltration of some organs This is an observation which may prove of considerable importance to our understanding of the nature of age changes in the body

A shift in the distribution of subcutaneous fat which parallels the shift in body form vectors also occurs in the three age subgroups If we divide the body at the waist into an upper and a lower region in Subgroup A (young [see Table 2]) the upper region contributes 40 per cent to the total thickness of the subcutaneous adipose tissue, whereas in Subgroups B and C the contribution is 44 per cent and 46 per cent, respectively Similarly, if the adipose layer of the axial region of the body is compared with that of the limbs, a shift in the concentration of subcutaneous fat from the limbs to the trunk is noted Thus the adipose layer of the axial region in the younger group is 47 per cent of the total, while in the two older age groups this proportion increases progressively to 50 and 53 per cent

TABLE 2*

PERCENTAGES OF BODY FORM VECTORS PRESENT IN THREE DIFFERENT AGE GROUPS OF WOMEN

Vector	Age Group		
	A 18 30 (N=31)	B 31 45 (N=25)	C 46 67 (N=28)
Normal (N)	92 8	56 0	51 8
Rubens (R)	3 7	16 0	22 2
Superior (S)	3 7	8 0	3 7
Inferior (I)	25 9	28 0	18 5
Truncic (Tr)	0 0	20 0	14 8
Extremital (Ex)	7 4	4 0	7 4
Trochanteric (T)	11 1	12 0	25 9
Mammary (M)	3 7	8 0	18 5
Pseudosteatopygous (P)	0 0	0 0	3 7
One vector types	55 7	52 0	40 7

* Source Skerlj *et al* (1953

RELATIVE FAT PATTERNING

Garn (1955) criticizes Skerlj s and other classificatory systems for lack of quantification although he admits that their descriptive "designations are often devastatingly good To circumvent this objection, Garn adapts the familiar psychometric practice of constructing standard score profiles using fat thickness at nine specific body sites as his basic measurements Mi

crometer caliper measurements of subcutaneous fat "shadows" as seen in soft-tissue X rays are taken in the various locations indicated in Figure 4 These are then transformed into standard z scores, which relate each measurement to a normative group in terms of its standard deviation from the mean of that group Thus a z score of 1 indicates that the particular measurement in question falls 1 standard deviation above the mean for that particular site in the reference group Of

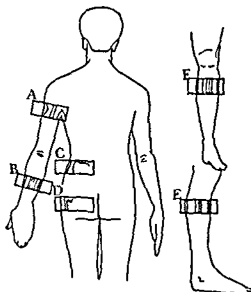


FIG 4—Locations of X ray sections used in studies of fat patterning *A* deltoid insertion section, *B*, lower arm section, *C*, iliac section, *D*, trochanteric section, *E*, anteroposterior leg section (lateral view), *F*, transverse leg section (*A–P* view) (After Garn, 1954, Fig 1)

course, a zero score would fall at the mean of the norm group, and negative scores would fall below the mean In this way the absolute thicknesses of the fat layers, which differ widely for the various body sites, can be ruled out and the individual's "fatness" expressed in relative terms (Garn, 1955*a*, 1955*b*)

In Figure 5 a graphic representation of both the absolute measurements and the relative scores of two hypothetical individuals is given in profile form The upper graphs show clearly the variations in thickness of the fat layer for the different sites measured In the lower graphs we see that one of the sets of hypothetical measurements (*left*) was in every instance at the mean of those of the standard group, so that all z scores are zero The profile of the other individual reveals above average thickness for arm and pelvic fat combined with low leg fat thickness The statistic σz (relative fat variability) refers to the standard deviation of each individual's own fat thickness measurements and is, therefore, a measure of "the extent of individual variability in subcutaneous fat patterning, corrected for the amount of fat present" (Garn, 1955*b*)

Using these profiles, Garn was able to identify some of the fat patterns already described in the literature, but a high percentage of his cases defied apparent classification Relative fat variability (σz) was found to be the same in a group of 38 younger men (mean age 30 4 years, $\sigma z =$ 0 62) and in a group of older men (mean age 48 1 years, $\sigma z = 0$ 61), suggesting that this measure is unaffected by age in spite of the tendency toward increase in fat thickness This fact is consistent with Garn and Harper's (1955) conclusion that age increase in fatness in men does not differ in pattern from simple fattening in young men Similarly, in weight reduction no change in relative fat patterning occurs in males, although an absolute diminution takes place in fat thickness in all measured reduction methods, for these findings suggest that the entire subcutaneous fat layer is affected in equal proportion by diet restriction

AGE CHANGES IN SOMATOTYPE

Other evidences of change in body build have been presented The Hooton and Dupertius (1951) study of changes in bodily measurements with age, already alluded to above, is replete with objective data on this

point Although the study is largely de scriptive, its value cannot be overestimated because of the completeness with which the basic data are presented No attempt, how ever, is made to present a picture of the over all changes in the body configuration through the use of a classificatory scheme Newman (1952), however, has used a method devised by Hooton to study age changes in somatotype in a male army pop ulation composed of some 4000 individuals aged 18–35 years The purpose of the New man study was to explore the assertion of several investigators that the somatotype, at least in normal males who had com pleted their skeletal growth was permanent and therefore would not change during the postmature years In the army series with which Newman worked Hooton had al ready identified 126 somatotypes 80 of which had frequencies of less than 1 per cent Age analysis of cross sectional sam ples of this population showed that, con trary to previous expectation definite al though limited changes in somatotype com ponents occurred with age

CLOTHING AND SIZING SYSTEMS

There is no indication from this or from the other studies of the age changes of the body form reported here that any neces sary change in behavior, attitudes, or ad justments accompany these structural changes The conviction that they are be haviorally significant rests almost entirely upon each individual s idiosyncratic expe rience and observation Yet the body and its form are things with which each person must deal Gradually and slowly, he be comes aware of changes to which he must adjust Not all changes influence function nor are functional changes always the most significant to the individual The social sig nificance of the body object leads to the emergence of the tremendously high values which are placed upon appearance While appearance is based primarily upon body structure within very broad limits it may be influenced by other factors, such as pos ture clothing cosmetics, and grooming How these factors influence social and self acceptability remains an art as yet not im

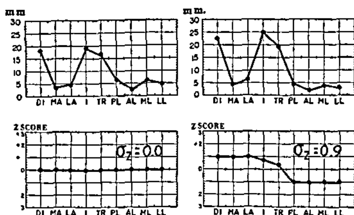


Fig 5 —Comparison of absolute fat patterns (*above*) and corresponding relative fat patterns (*below*) *Left* hypothetical ind vidual exactly at the mean in all nine fat thicknesses His mean *z* and fat variability score (σz) are both zero *Right* hypothetical individual with relatively thick arm fat and relatively thin leg fat Though the difference between the two men is evident in the absolute fat patterns it is striking in the rela tive patterns and in the fat variability scores

The abbreviations *DI MA LA* etc refer to deltoid insertion fat medial arm fat lateral arm fat iliac fat trochanteric fat posterior leg fat anterior leg fat medial leg fat and lateral leg fat (From Garn 1955*b* Fig 1)

portantly touched on or investigated by science

Body size and clothing fit are nevertheless inescapably related In recognition of this fact sizing system have been developed based upon various national samples (O Brien and Shelton, 1941, Sittig and Freudenthal, 1951, Board of Trade, 1957) Careful anthropometric work on large and fairly representative groups has produced data of interest to the clothing industry and to the scientist alike Sizing systems to be practical must reduce the almost infinite number of possible variations in body form to a limited number of dimensions

TABLE 3*

PERCENTAGE DISTRIBUTION OF WOMEN S SIZES BY AGE

Age Subgroup	Hip-Girth Size (Inches)				
	36 and Smaller	38 and 40	42 and 44	46 or Larger	All Sizes
18–29	39	28	11	4	27
30–44	40	38	29	22	36
45–64	21	34	60	74	37
Total	100	100	100	100	100

* Adapted from Board of Trade (1957) *Table 73* p 77

Clothing sizes based upon these dimensions must be devised so that the entire range of the normal population may be fitted adequately Naturally, the number of different sizes must be kept reasonably small in order to avoid unnecessary duplication and waste

In effect, this process is a kind of applied somatotyping, and it is perhaps not entirely coincidental that some agreement should be found between the results of pure and applied research in this area Curiously, the Joint Clothing Council report recommends a sizing system for women's clothing, based upon extensive anthropometric investigation, comprised of 126 different sizes (Board of Trade, 1957) This is exactly the same number of somatotypes identified by Hooton in the sample of relatively young men referred to above (Newman, 1952) The similarity is carried further when we realize that both systems identify 46 main types or sizes in terms of frequency of occurrence

Table 3, based upon the Joint Clothing Council Study, shows the expected shift toward large sizes with increasing age Indicated here is the preponderant proportion of older women in the larger dress sizes represented in this system by hip girth Also to be noted in the table is that no size applies exclusively to any age group however only a very small percentage of women from the youngest age group falls in the sizes above 42 inches

Age change in body proportion is also reflected in the size charts, but for simplicity's sake these are held to a minimum Of the 37 body measurements, only 3 were considered to reflect sufficiently great age changes so as to require separate listing for the three selected age subgroups young women (18–29) women aged 30–44, and older women (45–64) These three age-influenced dimensions are waist girth, abdominal extension girth, and the neck-to-bust dimension which extends from the base of the neck to the greatest prominence of the bust. Each of these measurements tends to be larger in the older groups than in the young group for all sizes In the age group 30–44 these dimensions appear to show some interaction with body sizes as indicated by hip girth Thus for the smaller sizes (32–38 inch hip girth) these measurements are close to those of the young group but for larger sizes (44–52) these dimensions become increasingly like

[illegible]
in this report the clear association of age with larger sizes is strikingly apparent Since certain styles of clothing are considered more suitable for older women, it would appear natural for a concentration of these styles to appear in the larger sizes, thus effecting an inevitable age relation

ship among style, size, age, and, ultimately, appearance Investigation of these relationships should be most interesting What, for example, is the influence of body size upon self concept and upon acceptance of and adjustment to age roles? To what extent is small size and youth associated in the formation of age stereotypes? How does body size and shape affect adjustment to aging? How do these variables influence the selection of clothing? What compensatory measures are commonly taken, and do these have any significant relationship to the quality of adjustment of the individual? These and many more relevant questions could be asked about the influence of this particular aspect of the body environment on the behavioral organization of the aging individual

Data bearing upon some of these questions are provided in the Joint Clothing Council report and was gathered incidental to the major aim of the study Since most of the anthropometric measures reported were taken over the foundation garments worn by the subjects, it was important to assess the influence of this condition upon obtained measurements From comparisons of measurements with and without foundation garments, it was concluded that, while many statistically significant differences in measurement were obtained, most of these were small and of no practical importance Admittedly, however, the measurements used were not intended to give a complete account of the changes in body form brought about by foundation garments, nor, it might be added, are the averages of certain measurements likely to provide full answers

Table 4 shows the distribution of the sample by foundation garment worn and by age Here clear age differences in preference becomes apparent, with the older women selecting, by a considerable majority, garments offering more firm and rigid support This finding is entirely consistent with the reported age-related increases in body weight and of subcutaneous adipose tissue already discussed Whether this relationship applies only to this particular British sample is, of course, uncertain

TABLE 4*

PERCENTAGE DISTRIBUTION OF A SAMPLE OF 4995 WOMEN BY FOUNDATION GARMENT WORN AND BY AGE

Age	Suspender (Garter) Belt and Brassière	Brassière Only	Roll-on and Brassière	Corset and Brassière	Corselette	Other	Whole Sample	
							Per Cent	No
18–29	38	17	35	8	1	1	100	2366
30–44	20	8	37	27	3	5	100	1554
45 and over	6	2	20	59	7	6	100	1075
All ages	25	11	32	25	3	4	100	4995
Reweighted age distribution	20	8	30	34	4	4	100	

* Adapted from Board of Trade (1957) Table 54 p 54

THE AGING FACE

Age changes in the human face can be judged in two ways anthropometrically and artistically From the former method we obtain precise measurement of change, feature by feature, along well defined dimensions, from the latter we learn the major relationships which lead to the total perception of the effects of aging on the face. Hooton and Dupertuis (1951), effectively utilizing painstaking anthropometric methodology, give a comprehensive descrip-

tion of facial age differences in their study of almost 10 000 Irish men already referred to previously Certain of the differences described by these investigators are fairly obvious and expected, others are less so Among the differences they report are the following a tendency toward an increase in thickness of the nasal tip with advancing age a decrease in the frequency of occurrence of the concave and straight nasal profile with an increase in the convex pro-

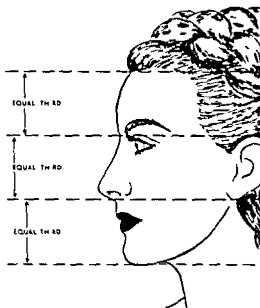


FIG 6—The youthful face may be divided into three areas of equal vertical dimensions (After Brown, 1953)

file, a decrease in membranous thickness of the upper lip, probably resulting from fat loss plus some inrolling or inversion due to loss of teeth and absorption of alveolar processes, a decrease in eye opening height a decrease in eyebrow thickness, a change in contour of face resulting from loss and wearing down of teeth, and an increase in size of ear lobe

Listing of these differences does not, however, give any more than a suggestion of their perceptual significance in estimating the age of the face We do not know which of these are noted by the individual or the value they may have for him Brown (1953) provides an answer to at least some of these questions by analyzing what he refers to as the "artistic anatomy of the face" The appearance of aging in the face, he believes, results from an alteration of relationships between three basic dimensions of the facial profile plus certain other changes As illustrated in Figure 6, the youthful profile is divided into three *equal* areas the forehead, the nose, and the nose-to-chin length When the nose takes up more than its one third of the profile, thereby reducing the proportion allotted to the lower part of the face, the appearance of age is given Brown believes that the critical dimension in determining the characteristic age of the face is the lower third of the profile from the bottom of the nose to the bottom of the chin

Brown lists the etiological factors in facial senescence as follows atrophy of skin, facial muscles, and connective tissue attachments of skin to muscle, wearing down of teeth with consequent lessening of vertical dimension of the lower third of the face absorption of mandible and other facial bones, bringing the chin closer to the nose than in youth, atrophy of elastic tissues of the nose resulting in elongation in the vertical direction, appearance of wrinkles bags, and folds in the skin of the cheeks because skull, teeth, and other contents no longer fill the skin as fully as in youth, and baggy eyelids and overhanging of upper lids resulting from redundancy of aging skin

III Compensatory Reactions to Changes in Appearance of the Body Environment

Undoubtedly the first portentious signs of aging are subtle modifications of appearance resulting from the changes in the body form described above Awareness of these effects may be met with placid acceptance or even with great satisfaction when they are looked upon as signs of mature stature finally achieved On the other hand, fear of

the personal and social consequences of aging may lead to compensatory steps designed to retard or to reverse this unwanted aspect of aging To achieve these ends, four lines of action may be followed (1) adoption of youthful dress, (2) use of cosmetic aids and careful grooming, (3) conscious assumption of more youthful attitudes and behavior and (4) attempts at direct alteration of the body form

Curiously, there is a dearth of systematic investigation of these various compensatory devices Study of the influence of dress style and of cosmetic aids as they relate to aging should prove a rich field of psychological investigation yet little has been done in this area Attitudes and activities in relation to age have received a substantial amount of research attention, but we do not know whether youthful activities and attitudes retard the effects of age or result from retarded senescence Great interest has for many years been attracted by attempts at the rejuvenation of appearance by the removal of what might be considered age stigmata yet the psychological implications of these efforts have received scant notice There is no question however, that the latter approach can lead to striking reversals in the apparent age of the individual Principally achieved through weight reduction and by the intervention of plastic surgery the gains although no more than temporary should attract considerable gerontologic interest

REJUVENATION OF APPEARANCE THROUGH WEIGHT REDUCTION

We have seen that an increase in body weight through the accumulation of fatty tissue chiefly in the axial portions of the body produces characteristic changes in body contour which are age related Although most conspicuous in greatly overweighted individuals, the desire to reduce is by no means restricted to this group While other reasons for this desire abound, it may be presumed that a fundamentally compelling one is the wish to regain or retain a youthful, attractive figure

No satisfactory answer is as yet available to explain the steady accumulation of fatty tissue during middle life, although a number of reasons have been advanced particularly for the excessive gains in weight leading to obesity Diet is undoubtedly a factor, although its precise influence is unknown

CAUSES OF OBESITY

Overeating is most frequently blamed as the basic cause of obesity Brosin (1953) says that while organic factors may be operative, most evidence points to excessive intake of food as being the basic factor This in turn, he believes, is but a mani

between individuals in what constitutes caloric excess This they feel, indicates that other factors are of vital importance, notably the amount of physical activity (Skerlj *et al*, 1953, Mayer, 1955*a*)

Mayer for example, believes that genetic traumatic (chemical and surgical), and environmental etiological factors lead to three types of obesity (1) metabolic, with lesions involving biochemical mechanisms, (2) regulatory involving central nervous system dysfunction, and (3) inactivity, that is, low energy expenditure and only relative hyperphagia (Mayer, 1955*a*) Caustically, this author says that sedentary living "without development of obesity means that either the individual will have to step up his activity or be mildly or acutely hungry all his life" (Mayer, 1955*b*) She feels that overeating is a completely inadequate explanation of obesity

Psychodynamic interpretations, according to Brosin (1953), center about four response types (1) reaction to non specific emotional tension, (2) substitute gratification in the face of severe frustration, (3) symptomatic response to underlying emotional illness; and (4) food addiction

Some writers contend that certain forms of obesity represent neurotic defenses of such importance to the patient's unstable personality structure that attempts at weight reduction without correction of the underlying neurosis are doomed to failure

CONTROL OF OBESITY

Acceptance of psychodynamic factors as having important etiological significance has led naturally to the development of psychotherapeutic and motivational approaches to the problem of weight control (Weiss 1953) The development of nutritional clinics and various other forms of group methods has been met with sufficient success to warrant continued exploration of these methods Schwartz and Goodman (1952) report that a group of nineteen elderly obese diabetic patients achieved an average weight loss of 15 8 pounds during 1 5 years of group therapy and at the same time made important psychological gains Other reports point to the importance of the group in providing motivation (Chapman 1953) and to the probable advantage of emotional screening of patients for weight reducing clinics (Young *et al*, 1955)

Many questions remain unanswered concerning the effects of weight reduction on body composition and form While it is known that fat decreases more quickly than body weight with restriction of food intake, and gains proportionately faster with the resumption of normal diet, the pattern of this depletion is not known (Brozek and Keys 1951) Does it differ at varying ages or between the sexes? In weight reduction do certain parts of the body lose weight more readily than others? Research answers to these questions are still to be sought (Skerlj *et al* 1953, Garn, 1955*b*)

COSMETIC SURGERY

There is no more direct approach to the rejuvenation of the body form or body environment than by the surgical removal of the visible stigmata of aging The fact that such operations are performed is of considerable interest from several psychological vantage points Successful correction of age associated physiognomic faults should be helpful to the understanding of the contribution of various facial features to the appearance of age in the total facial *Gestalt* In addition, study of the motivation for surgical "rejuvenation" should reveal to some extent at least the impact of the aging of the body environment upon the individual's adjustment. Reactions to the results of the operation itself can also provide some information concerning the influence of visible signs of aging upon personal adjustment

That the appearance of youthfulness can be achieved surgically is amply demon

Figure 7, *A* and *B* In this patient the remarkable reduction in apparent age was effected by the artistic application of the surgical methods recommended by Brown Seltzer (1952*a*, 1952*b*, 1954) also describes this type of operation and recommends its broader adoption

PSYCHOLOGICAL IMPLICATIONS

Psychological considerations are of supreme importance in 'rejuvenative" cosmetic surgery The motivation behind the patient's request for this service deserves the most careful scrutiny for the protection of both surgeon and patient. MacGregor (1953) points out that surgery which may deprive a patient of his neurotic defense may ultimately place his mental health in serious jeopardy There may be good reasons for requiring such surgery—personal as well as economic—but these should be ascertained MacGregor lists the following signs which contraindicate cosmetic surgery and supports these with case histories of unsuccessful experiences confused vague and unconvincing explanations for the request, irrational motivation in terms of the demands of the actual situation, ex



A



B

FIG 7—*A* Premature facial senescence Note the pendulous upper eyelids the age l nes about the mouth and the beginning evidence of hang ng jowls Age 36 (After Brown 1953) *B* Rejuvenat on by eliminat on of redundant facial skin and correction of baggy upper eyel ds and dental prosthet c work to correct the bulging anterior teeth Judicious make up (After Brown 1953)

cessive unrealistic expectations of results dissatisfaction with results of previous cos metic surgery history of psychiatric dis turbances lack of insight into personal problems tending to project the source of difficulties outside the self request to elim inate feature like that of rejected or re jecting parent and request due to pres sure from others This list reveals qualita tively at least the deep psychological sig nificance which can be attached to facial features and the possibility of these charac terist cs assuming a dominant role in the adjustment pattern of the individual

Lacking a comprehensive analysis of large numbers of cases surveys of limited case material plus the impressions of sur geons directly involved with the patient suggest that the results of surgical removal of physiognomic stigmata including those produced by aging can be wholly satisfac tory Seltzer (1952*a*) says that the purpose of the operation is to remove from the face something that acts to interfere with the satisfied pursuance of usual daily living He believes the removal of age produced blemishes to be no less important psychologically for some individuals than the correction of disfigurement produced by injury or disease Failure on the part of the public and the medical profession to recognize this leads to the relegation of this service to ill trained and even illegal oper ators to satisfy what he believes to be an unmet demand (Seltzer 1952*a* 1952*b* 1954)

Hill and Silver (1950) commenting on the results of facial surgery for the removal of wrinkles say

> The change is realistic enough to account for the almost universally happy response For cer tain reactive depressions such as occur in some ind viduals follow ng the death of a spouse the reduction of severe aging wrinkles in addition to supportive psychotherapy has g ven remarka ble results and good prognosis in lieu of pro longed psychotherapy or electric shock For in volutional depressions this procedure is of less value [p 352]

Other writers also have stressed the psychological aspects of cosmetic surgery (Perlman 1951 Straith and Millard 1951 Hollander 1954 Robertson 1955) Certainly these direct attempts to reduce or to eliminate signs of aging in the body environment serve to emphasize the critical place the body form or environment has in influencing the attitudes and the behavior of the individual Unquestioned need exists to study more systematically this important behavioral area

IV Environmental Factors Related to Sensory and Perceptual Change

Since the organism can respond directly only to those aspects of environment experienced through sense organs age changes in sensory and perceptual mechanisms effect very real environmental changes in the world in which the aging individual lives Diminution in sensory acuity is one of the more distressing features of aging

Compensation for this loss in acuity is achieved either by enhancing environmental stimuli so that they may cross heightened sensory thresholds or by reducing dependence upon the affected sensory cues with consequent limitation of the range of behavior In the latter instance the individual learns to adjust to or to live in an environment different from the one he knew before experiencing sensory impairment In the former situation he seeks to modify his environment to make up for his deficiency These environmental modifications may be of two types (1) amplification or enhancement of the stimulus as it impinges upon the sense organ (e g by increasing sound intensity through use of a hearing aid) or (2) augmenting the stimulus intensity itself (e g by increasing intensity of illumination to improve vision)

In the following sections the environmental implications of age diminished sensory acuity and perceptual ability will be discussed Since the factual and theoretical material on this subject is presented in detail in chapters xv and xvi, repetition will be avoided here Nevertheless it is important to stress the environmental implications of these facts and this is an intended objective Again we will see that the great bulk of the work in this area deals with problems of vision and audition and this will be reflected in the discussion In addition thermal sensitivity will be discussed in its broadest implications including as a matter of convenence climate and environmental atmospheric conditions as well as temperature

Aging and the Visual Environment

Elsewhere in this book details of the changes which occur in the aging eye are set forth Here we are concerned with only one aspect of this problem—the environmental conditions under which the aging visual system functions optimally

Illumination Size Contrast

Comfortable and efficient vision depends upon several interrelated factors size of the object contrast in brightness between the object and its background amount of illumination glare and position of the object (Ferree *et al* 1935 Weston 1953 Murrell 1957) Since age introduces marked effects on the requirements for optimal vision each of the above factors to a greater or lesser extent is affected by these changes

The intimate relationship between age illumination size and contrast is nowhere better shown than in Weston s work with these factors which is presented in some detail in chapter xv Weston s subjects ranging in age from the early twenties to the late forties were tested on a visual task under varying conditions of contrast and illumination The results clearly showed that regardless of the amount of illumination visual performance decreased with age This is shown not only by the consistent drop in performance between age groups but also by the decline in visual per

formance in the same individual retested after a 5 year interval (Weston, 1948, 1949)

In addition, the smaller the test object (gap in Landolt rings), the steeper the age decline in performance, and, the lower the level of illumination, the greater the drop When these facts are viewed in another way, it becomes apparent that visual performance declines less with advancing age under conditions of high illumination than when illumination is relatively low It also suggests that in some measure increases in the level of illumination compensate for age induced loss in visual efficiency

Unfortunately, full compensation was never fully achieved, although increasing the amount of light improved the performance of the older subjects markedly It is well to note that several of the older subjects were completely unable to perform the finest visual task under conditions of poorest contrast and lowest illumination even though younger subjects could carry on at reduced levels of efficiency Thus we are led to conclude that in fine close work of the sort used in these experiments it is indisputably important to provide persons in their late thirties and older with high levels of illumination even though they exhibit no apparent visual defects Even more important, so Weston believes, is the use of suitable optical aids to increase the perceived size of the visual object

OBJECT SIZE IN A COMPLEX TASK

While we are not primarily concerned here with underlying neurophysiological mechanisms it would probably be wrong to attribute the effectiveness of increasing size and amount of illumination solely to peripheral visual factors It may well be that the increasing of sensory input is a general requirement for effecting compensation for age related losses in efficiency in both central and peripheral neural mechanisms In the Weston studies purely visual aspects of performance predominate because of the nature of the task and the experimental conditions Thus the size of the smallest test objects approached threshold values and, indeed, for older individuals under low illumination were actually subliminal Arms and Kleemeier (1953), on the other hand have demonstrated on a more intellectually complicated task that an increase in object size alone is accompanied by an improvement in performance in an aged group which cannot be considered as a function of visual acuity

In the latter study, 128 male subjects ranging in age from 20 to 84 years were given the Picture Completion Test of the Wechsler Bellvue Adult Intelligence Scale (Forms I and II) in both the standard and an enlarged size This test consists of a series of line drawings each of which has missing some essential part Subjects are required to identify the missing detail The larger pictures were approximately three times the standard size To half of each age group the smaller pictures were presented first, and to the remaining half the larger were presented first

Results of this study are presented in Table 5 From this we see that increased size of the test pictures had no effect upon the performance of the younger group but leads to a significant improvement in the aged group For the older group, when age is held constant a partial correlation of 20 was found between visual acuity (Ortho-Rater) and performance on the standard pictures Since the corresponding partial correlation between visual acuity and the enlarged pictures is 28, it is difficult to support the hypothesis that the improved performance on the enlarged pictures can be attributed primarily to visual acuity, even though both correlations are statistically significant

In view of this finding, it may be that the larger dimensions of the display permit the older individual to devote fuller attention to the significant aspects of the task by reducing the number of irrelevant cues in the visual field This reduction in competing stimuli should result from the increased area of the visual field being occu

pied by the test object Regardless of interpretation however this study again suggests that the performance of older people on visual tasks, when compared to that of younger people is aided disproportionately by increases in object size

AGE RELATED CHANGES IN PUPIL SIZE AND ILLUMINATION REQUIREMENTS

The pupil of the eye responds reflexively to changes in amount of illumination As the amount of light increases the aperture of the pupil diminishes in diameter as the illumination decreases the pupil widens to permit the entry of more light As age advances the response range of the pupil diminishes (Crouch 1945 Birren *et al*, 1950)

This diminution in size of pupil affects the visual requirements of the aging eye by increasing the amount of illumination necessary for it to receive an amount of light on the retina equivalent to that received by the younger eye at the same level of illumination Crouch (1945) basing his calculations upon the theoretical work of Moon and Spencer (1944) relates the brightness needs of the older eye with its diminished pupillary size to the equivalent requirements of the 20-year old Taking the brightness necessary for optimum conditions of visual acuity, contrast and speed of vision for the normal 20-year old eye as a base, he estimates that at age 45 it will be necessary to increase brightness by 50 per cent to reach optimum conditions of acuity contrast and speed By the late fifties a 100 per cent increase in brightness will be required and by age 80 an increase approximately three and a third times the value for the 20 year-old level is necessary

Ferree *et al* (1934 1935) give five reasons why the old eye needs more light than the young eye (1) its pupil is smaller, (2) the imaging power of its refractive media is less (3) the transparency of the media is diminished, (4) its processes of adaptation and adjustment are relatively poor and (5) the power of the retina itself is reduced These reasons however explain only in part the superior enhancement of visual performance accompanying increases in illumination which is experienced by the old when compared to the young The work of Weston (1948 1949) and of Arms and Kleemeier (1953) indicates the probability of central as well as these peripheral factors exerting influence on this phenomenon

TABLE 5*

COMPARISON OF MEAN PERFORMANCE SCORES ON THE PICTURE COMPLETION TEST PRESENTED IN TWO SIZES (STANDARD AND ENLARGED) TO TWO AGE GROUPS OF MALE SUBJECTS

	Standard Size	Enlarged Size	Difference between Sizes	*t*
Young group age 20-59 (N=64)	10 73	10 67	−0 06	0 27
Old group age 65 84 (N=64)	6 61	7 73	1 12	4 91†
Difference between ages	4 12	2 94		
t	9 14†	6 59†		

* Source Arms and Kleemeier (1953)
† $P < 0\ 001$

In view of these considerations, Ferree and his associates strongly recommend that older patients be advised by their physician of the levels of acuity which they can attain at different intensities of illumination in order that they may better appreciate their dependence upon good lighting

AGE AND NIGHT VISION

As the eye becomes accustomed to low levels of illumination, its sensitivity to light becomes remarkably enhanced, and some of its visual characteristics change The fovea, or central part of the retina, which is the spot of keenest daylight vision, becomes at night less sensitive than the surrounding, peripheral areas of the retina Briefly, the characteristics of night vision are great sensitivity to brightness, diminished capacity for form perception, and a shift of the most sensitive areas from the center to the periphery of the retina Details of these various changes are discussed in chapter xv, and many of the derived environmental implications are presented in chapter xiv, nevertheless, some attention must be given to this area here

Individuals who are handicapped in the process of dark adaptation invariably have difficulty in seeing at night It is hard to say, however, at just what point a major problem exists, because this depends upon the nature of the activity or task required of the individual and the quality of his compensations McFarland and Fisher (1955) estimate that, for every increase of 13 years in age beyond age 20, the threshold intensity of illumination must be doubled to be seen by the fully dark adapted eye The implication of these findings to the environmental needs of the aging person are important and direct While it may be argued that these studies are based upon thresholds and, therefore, set minimum values only, it must be remembered that in *night vision threshold intensities are of* great importance because much of the visual field will be subliminal even to the best of eyes In providing the good visual night environment for older people, two objectives should be kept in mind (1) the achievement of high levels of illumination consistent with the visual characteristics of the eye and (2) the elimination of anything which may prevent all available light reaching the eye

To satisfy the first objective requires a study of both indoor and outdoor lighting as well as of the conditions under which the eye functions best Illumination which seems perfectly satisfactory for the ordinary requirements of the young person may actually place the aged individual under a severe handicap More older people would do well to supplement available light when out of doors at night by use of flashlights In night driving it would follow that the older driver would derive less benefit from his headlights and would have a more restricted range of vision than the young driver Good general road illumination, while benefiting all age groups, would be most helpful to the older person

Satisfaction of the second objective is in most instances easier to achieve A common way of reducing the amount of light reaching the eye is the use of colored glasses or tinted windshields in automobiles McFarland and Fisher (1955) feel that such devices, particularly when used by individuals over 55 or 60 at night, raise serious questions of safety Since the decrease in night visual sensitivity is an insidious development likely to go on unnoticed by the individual until some real inconvenience calls it to his attention, it is probable that the individual in looking for an assumed protection against glare is unaware of the disadvantage under which he places himself at night by using these devices which cut down the general level of illumination reaching his eyes Glare is, of course, a problem, but it is one which should be attacked at the source, and the solution should not be detrimental to the general level of illumination

GLARE

A distracting or disturbing brightness in the field of vision is referred to as glare It may simply produce discomfort, or, if bright enough and in competition with the object being viewed, it may markedly impair visibility (Crouch, 1945, Murrell, 1957) There are two major reasons why glare handicaps good vision In the first

place the eyes tend to be attracted to the brightest place in the visual field If this does not happen to be the task at hand effort must be expended to keep the eyes away from the offending source Second glare tends artificially to raise the level of light adaptation of the eye thereby casting a veil of light over the entire visual field (Crouch 1945) In effect glare raises the level of background brightness making it difficult for the eye to distinguish small differences in contrast

In Figure 9 of chapter xv the marked decline with age in ability to perceive contrast is shown (Bouma 1936 1947) In the presence of glare these age differences are enhanced Note particularly in these graphs that the drop is unambiguous with the performance of the 40–50 year old group clearly below that of younger subjects In addition it is significant that even the performance of subjects in their mid twenties and mid thirties is well below that of younger subjects when glare is present although in the absence of glare no age difference in contrast sensitivity could be reliably inferred earlier than age 40 Bouma specifically emphasizes the additional difficulties likely to be experienced by the older person under ordinary conditions of night driving in the face of glare from oncoming traffic road illumination and reflections

VISUAL FIELD

An additional night vision hazard for the older individual results from the contraction of the rod field of the dark adapted eye which incurs a progressive lessening of the limits of peripheral or side vision at low illumination This observation is based upon the work of Mann and Sharpley (1947) who report a mean radius of the visual field of the dark adapted eye to be about 60° for subjects between ages 10 and 40 and 52° 53° for older subjects up to age 60 It would be interesting to extend this study into ages beyond 60 as well as to confirm the findings at the earlier ages with an increased number of subjects

USE OF COLOR TO LESSEN VISUAL HANDICAP

Color may be used in two ways to reduce to some extent the visual handicaps of age (1) by proper selection of surface colors and (2) by effective use of the color characteristics of light sources Bouma (1947) convincingly demonstrates the latter by comparing the effectiveness of three kinds of artificial illumination as applied to road lighting showing that sodium light as contrasted with incandescent and mercury light offered certain advantages in improving the striking power of contrasts (see chap xv)

Bouma relates this fact to rod and to cone function At high levels of brightness vision is exclusively a cone function however as brightness diminishes rods become more and more involved until at a level equivalent to a moonless starry night vision is exclusively a rod process At in between levels both types of receptors function Rods and cones are differentially sensitive to various spectral wave lengths with the cones being more sensitive to long waves (yellowish green) and rods to the short (bluish green) At very low intensity levels (rod vis on [illegible] fore [illegible] both rods and cones are functioning therefore a reddish road light (e g sodium) would adequately illuminate most of the visual field Dark objects falling on the darkest part of the visual field however would as a result appear extra black against a lighter background such as that presented by the road surface This is what is referred to as the improved striking power of the contrast with sodium illumination

Bouma however does not comment on the possibility of reduced peripheral vision with sodium lights owing to the greater concentration of rods in the retinal periphery Furthermore in view of the age related reduction in rod fields reported by Mann and Sharpley (1947) sodium lighting might provide an additional visual

handicap for the aged by causing a further diminution in the scope of their peripheral vision This possibility deserves investigation

Sodium light apparently is better than the incandescent light in terms of recovery from the aftereffects of glare Recovery times from exposure to white glare were

than that of the incandescent light Furthermore, sodium light proved superior to the mercury and incandescent light in terms of the just perceptible contrast as measured by the visibility meter under various road conditions

The use of surface colors to help vision as age advances is essentially a matter of improving contrasts in order to aid visibility and of increasing brightness where desirable by using colors with high reflective factors Increasing illumination at the source can be defeated by an abundance of dark reflecting surfaces Paint can eliminate dark corners as effectively as increases in artificial illumination Danger spots can be marked with sharply contrasting colors The aesthetic effect of color cannot be ignored There is no necessary relation between old age and somberness of color in habitation and dress yet the popular association is there Certainly study of age differences in color preferences would be interesting and informative

AN EVALUATION

The age differences and changes in visual capacity presented in this and other chapters of this book may appear to be overwhelming and hopeless unless one concentrates upon the residual capacities for visual performance In this respect, McFarland s comment is most helpful in putting these facts into practical perspective After exhaustive study of visual changes with age which might affect the aircraft pilot's skill he concludes, "Although there is a gradual impairment in visual functions with increasing age, the changes are not, on the whole, very marked' (McFarland, 1953) He believes, for example, that the wearing of corrective lenses should enable the pilot to continue to meet the visual requirements of his job until age 60 There are of course some visual deficiencies that cannot be relieved by glasses, but the effects of many of these can be ameliorated by proper changes in the visual environment In essence this means the provision for proper illumination, well directed and free of glare, and the effective use of the reflective properties of the surroundings (See also chap xiv)

AGE AND THE AUDITORY ENVIRONMENT

As may be seen in chapter xv, the sensitivity of the ear to high frequencies diminishes with age This loss of high tone acuity is an insidious process rarely noticed by the individual unless it is quite marked and has started to invade the upper speech frequencies At this point hearing difficulty is experienced, and the condition is known as presbycusis, or deafness of old age While high tone loss is universal in old age there are enormous variations in degree of severity

TWO TYPES OF AUDITORY IMPAIRMENT

The etiology of impaired hearing is manifold but basically the resultant disability may be placed in one or both of two classes —conduction deafness and nerve deafness In the former the sound wave is prevented from reaching the sense organs of the inner ear by some structural defect or obstruction This condition may or may not be reversible In its simplest forms it is transient and often self correcting, as, for example, in the obstruction of the auditory canal with wax or in simple congestion in the middle ear

Nerve deafness, on the other hand, results from neural degeneration in the sense organ itself, in the central nervous system, or in the auditory nerve Presbycusis is

typical of this type of deafness. This condition, moreover, is not reversible It is true that claims for relief through the use of various medical and surgical techniques have been made, but Morrissett (1950) fails to find any scientifically reliable and valid proof to support these assertions. Since both conduction and nerve deafness may occur together in the same individual a third classification, mixed deafness,' is also used

Degree of hearing loss can be determined either by measuring the relative pure tone thresholds in decibels (db) for various audible frequencies or by estimating its effects upon the reception of speech or other meaningful sounds While tests of both types can be carried out in the laboratory or clinic the vital significance of the loss must be gauged in terms of its interference with the individual s relationships with others There is a marked tendency to delay in the recognition of progressive hearing loss and to attempt concealing it after awareness of its inroads has been forced upon the individual

Mueller says that nobody will recognize a 10-db pure tone loss, but at 20 db friends and family will know it and at 30 db the patient himself will be aware of it (Hilger *et al*, 1954) Whether this is or is not correct has never been studied directly The National Health Survey data seem to indicate that awareness by others becomes general when the hearing loss reaches the 40 db level (Beasley, 1940)

Kleemeier and Justiss (1955) found that, *of a group of 41 aged men* with speech reception thresholds in excess of 40 db, well over half (59 per cent) considered themselves to be "hard of hearing" The remainder refused to accept this descriptive term for themselves Of 45 men in the same age group with speech reception thresholds under 40 db, only 1 indicated that he was "hard of hearing" Allowing for the lack of comparability of these various observations, they suggest, nevertheless, that a loss as high as 40 db will make it difficult for the individual to conceal his deficiency either from himself or from others

OVERCOMING AUDITORY IMPAIRMENT

Undoubtedly, auditory deficiency is troublesome to more older people than is commonly known The overcoming of this handicap is, therefore, an important objective in the development of environmental modifications designed to help the aging person

Compensation for hearing deficiency is achieved principally by amplification of sound either at the source or at the ear of the person concerned. The former method has two distinct disadvantages it may be disturbing to persons with normal hearing and it may impose an intolerable strain upon the speaker

SOUND AMPLIFIED AT SOURCE

In spite of inadequacies, the use of sound amplification at the source must be considered as important in any situation where spoken communication to elderly people is necessary Good sound amplification systems are essential in auditoriums and churches where a substantial number of elderly people comprise the audience. Younger people will not be ungrateful for such auditory assistance It must be remembered that what the normal ear hears with effort may completely escape the ear with even moderate hearing loss Auditory comfort demands a loudness level sufficient to achieve good comprehension with minimum effort. *Too much amplification*, on the other hand, can itself create discomfort What these limits will be depends upon the hearing characteristics of the particular audience

There is some basis for suggesting that the threshold of discomfort as well as the most comfortable loudness are relatively less influenced by the auditory impairments of age than is the speech reception threshold (Kleemeier and Justiss, 1955) This should indicate that a range of comfortable loudnesses could be determined which

would be well above the speech reception threshold of the average aged person yet which would not be offensive to the unimpaired ear While this may have to be empirically determined, the effort is eminently worthwhile in order to insure that maximum speech comprehension is achieved by the audience

In addition to amplification, the acoustical properties of the auditorium also have significant bearing upon auditory comfort The major objective of acoustical treatment of any inclosed space is to reduce extraneous noise either by preventing its passage through the walls or by absorbing sound to prevent its reverberation from wall and ceiling sufaces Any measure which will reduce background noise level will improve speech perception in both the normal and the impaired In presbycusis the ability to comprehend the spoken word is more markedly reduced by the presence of masking sound than in the normal ear under similar circumstances Proper acoustical treatment need not be reserved only for auditoriums, other public places such as restaurants and department stores and even houses can benefit from such work

HEARING AIDS

Since it is unlikely that the auditory properties of the environment can be adapted to the increased hearing needs of the aging to his complete satisfaction, compensation for any loss in hearing must in the main be sought in individual measures These vary from the monotonous repetition of "Eh?' or the cupping of the hand to the ear, through electronic sound amplification, to the reading of lips and expressive movements The first of these is intended to increase the loudness at the source, the second, to amplify the input at the ear, and the third, to substitute in some measure another sensory modality for the deficient one All the compensatory actions can be effective and mutually supplementary

It is natural, however, that the hearing aid should be thought of as the basic device through which the individual seeks to minimize the effects of his impairment Just as hearing loss is popularly associated with age, so increasingly is the hearing aid, and not without some justification Certainly, common observation would not lead one to dispute Berry's (1948) estimate that the average age of those who use hearing aids is 55 years

There is, however, much misunderstanding of the function, advantages, and limitations of the electronic hearing aid In the first place it must be thoroughly understood that the hearing aid does not restore normal hearing (Hughson and Thompson, 1943, Morrissett 1950, Lederer and Marcus, 1952) It is, as its name suggests, simply an aid to hearing with the distinguishing property of sound amplification Several writers have pointed out that much of the misinterpretation of the role of the hearing aid stems from a confused expectation based upon the efficiency of corrective lenses for refractice visual defects But hearing aids and glasses are different (Hughson and Thompson, 1943, Morrissett 1950) In the first place, hearing aids amplify the loudness of sound glasses do not add to the amount of illumination The characteristics of refractive errors the visual distortions they cause, and the necessary correction which must be ground into the lens are well known and can be accurately effected so that the restoration of sight can be immediately appreciated upon the donning of the lenses On the other hand the relationship of the pure-tone audiogram the effects of masking noise, and the selective amplification of audible frequencies to the perception of speech sounds is not entirely clear Consequently, auditory correction, though adequate and sometimes very satisfactory, is considerably less than perfect Furthermore, the accommodative mechanism of the eye permits rapid adaptation to sudden changes in amount of light, the ear does not similarly adjust well to sudden alterations of sound amplitude Finally, the relatively recent

development of the hearing aid when compared to glasses is perhaps reflected in its lesser degree of social acceptance and technical advancement

ADULT REACTION TO HEARING AIDS

In all the literature on hearing and deafness one finds practically no mention of studies of adult reaction to hearing aids (Barker *et al* 1953) Certainly lack of interest cannot stem from want of questions How many people who get hearing aids are satisfied with them? What are the factors associated with successful use of hearing aids by older people? How are hearing aids used and what difficulties are commonly encountered? Why do some persons accept hearing aids and others refuse to consider them even though they experience difficulty in hearing? What are the best methods of dealing with the hearing problems of the older person of examination and fitting of training him in the use of his hearing aid of helping him understand the nature of his hearing difficulty? How best to improve his speech perception whether or not he wears a hearing aid? These and many more questions require better answers than we are furnished with at present

In 1940 Day estimated that 75 per cent of the hearing aids purchased were promptly discarded Subsequent improvement in hearing aid design reduction in size and improvement of performance and style should indicate much greater success today but accurate estimates are not available Hughson and Thompson (1943) in a report of a study conducted shortly after Day s estimate was made found a considerably greater acceptance of the hearing aid in a group of 136 patients who were advised to secure them following an audiological examination Of the 97 in this group known to have purchased aids 70 per cent reported that they were either fully satisfied or satisfied with some reservation Fourteen were not satisfied with the instrument Among this group were those who felt self-conscious about wearing the aid even if it gave them some help In the older group lack of success with the aid was attributed to its failure to compensate for severe high tone loss

Kleemeier and Justiss (1955) reporting on the experience of 31 hearing aid users ranging in age from 67 to 90 found that 22 were satisfied with their instruments Only 5 were completely dissatisfied Ten of the respondents said that they put on their hearing aid in the morning and left it on most of the day while 8 reported that they seldom or never used their aids Both users and non users of hearing aids in this age group showed marked loss in high tone sensitivity but at all frequencies the combined audiograms of the users was considerably poorer than that of their comparable age peers Both the hearing aid group and a control group of like age reported difficulty in understanding speech but only the former would classify themselves as hard of hearing Since hearing aids were equally available to both groups at no cost it would appear that the wearing of a hearing aid is considered by the elderly as a measure of last resort—a step to be taken only when the hearing loss becomes very severe It is obviously not thought of by this group as a means of securing convenience and comfort in the face of troublesome but not disabling hearing loss

In another facet of this study the troubles encountered by elderly people in the proper use of hearing aids are described Some of these difficulties result from poor design of instruments and others from lack of precise understanding of hearing aid operation The replacement of vacuum tubes by transistors has greatly improved the usefulness of these instruments for aged people by reducing not only size and operating costs but also the number of batteries used and by increasing the length of battery life This latter feature lessens the number of times that batteries have to be changed always a problem to the aged user as well as eliminating confusion be

tween A and B batteries, repeated ill advised battery testing, etc Poor vision, reduced manipulative ability, and mental frailty, however, still lead to difficulty in changing inaccessible batteries, placing them in backward, hurting fingers in the process, inserting ear molds in the ear, keeping contacts clean, and failing to turn the instrument off properly Some of these faults can be overcome by proper design, others require patient training and willing learning on the part of the would be user Aged people learning to use a hearing aid for the first time require an instrument which is simple in design and foolproof in operation and maintenance

SELECTION AND TRAINING IN USE OF AIDS

The elderly person attempting to remedy his hearing difficulty may well encounter disappointment Lack of proper centers, where professionally competent staff can provide hearing evaluations places the patient in the difficult position of selecting a proper hearing aid on the basis of a welter of clever advertisements Even after thorough medical examination the final selection of an aid from among several competing makes and models may well remain his own responsibility (Hilger *et al* 1954)

Recognizing the difficulties of adult adaptation to auditory impairment and to hearing aids Lederer and Marcus (1952) demonstrated the effectiveness of a hearing program based upon examination, evaluation and training These authors believe that fitting the patient with the hearing aid is the last step in a process designed to provide maximum auditory perception with whatever residual hearing the patient may possess Proper meeting of patient needs starts with a complete otological examination and is followed by a comprehensive auditory evaluation made with full electroacoustic equipment by a trained staff

Hearing aids are not recommended for all patients but, whether they are to receive them or not, each is assigned to an auditory education class These classes of from eight to twelve patients each meet for four 2 hour sessions during a 2 week period Patients between 21 and 60 years of age are assigned to one class, and those over age 60 to another No upper age limit is set, the criterion being simply alertness and desire of the patient Success is reported with an 88 year old patient, and no difficulty is anticipated with older individuals with sufficient motivation and moderate alertness

Topics presented to the class include discussions of the personal and social significance of hearing loss, anatomical, physiological and pathological aspects of hearing an explanation to each patient of the nature of his own hearing loss, and instruction in the use of the hearing aid After the fourth group session, hearing aid selection is completed for those who will profit from its use

The process of auditory education is not considered complete until vocational plans, if these are indicated are worked out with the patient and the family is informed of the nature of the patient's problem in order that the home situation can be improved to fit better the patient's needs It is pointed out that, of all handicapping disabilities opportunities for suitable vocational placement are greatest for those with hearing impairment

The individual who conceals the fact that he wears a hearing aid and who at the same time has not completely compensated for his disability places himself in an ambiguous overlapping psychological situation (Kleemeier, 1957, 1958) Concealment of the aid may therefore be self defeating, at least in terms of good personal adjustment Proper evaluation and acceptance of the realities of the auditory situation and its imposed limitations are necessary precursers to the overcoming of the handicap On this point Lederer and Marcus (1952) say

> It would certainly seem that the patient who shops around for a hearing aid that he can hide,

is a patient who has been without the adequate preparation of auditory education No individual who has not been given the benefit of the gradual development of tolerance for amplified sound or no individual who has not been given the benefit of discrimination of speech sounds through amplification, or has been informed of the complete make up of the hearing aid and taught the skills of wearing an aid, will fare very well even with the best instruments [p 140]

NOISE

Exposure to environmental noise of high intensity can under certain conditions produce permanent adverse effects upon hearing which may be indistinguishable from those of presbycusis How much noise may contribute to the normally experienced loss in auditory acuity which is associated with increasing age is not known Undoubtedly, it is not responsible for all the loss that normally occurs, but, on the other hand, it cannot be safely assumed that only those ears which are subjected to obviously traumatic sound intensities are affected in any important way That exposure to high noise levels for long periods of time produces permanent hearing losses has been amply demonstrated McFarland (1953) believes that this accounts for the somewhat poorer tone sensitivity of airplane pilots than an unselected control group

Cox *et al* (1953) show convincingly that high noise levels in the working place can produce small but measurable losses in the relatively short period of 2 years Instant exposure to loud blasts can also traumatize the ear, but in this study the noise levels to which the workers were exposed were not extraordinary, being on the order of that produced by a subway train or a streetcar These authors compared the audiograms of spinners and weavers who worked in relatively high noise levels (about 95 db for frequencies under 4800 cycles per second for weavers and about 10 db less for spinners) with those of a control group who worked in what was considered to be a normal noise environment By testing the workers immediately after leaving their workplace and again on Sunday night approximately 40 hours after leaving the noisy shop, temporary losses in auditory sensitivity were identified It was found that, relative to the performance of the control group, a residual loss of 2 9 per cent (AMA) was sustained by the weavers and one of 0 5 per cent by the spinners While this loss would not noticeably impair the perception of speech, the cumulative effects of continued exposure bear serious consideration

In view of these and other results it is quite understandable that noise standards have been suggested Burns and Littler (1956), basing their estimates on the American Standards Association report (Rosenblith *et al*, 1954), recommend that the following sound pressure levels not be exceeded if occupational deafness is to be avoided

Below 150 cps	100 db
150–300 cps	90 db
300–600 cps	80 db
600–1200 cps	75 db
Above 1200 cps	70 db

These sound levels should give little or no loss at 1000 and 2000 cps for exposures during the ordinary work week for periods up to 10 years' duration Losses of no more than 5 per cent would be expected at 4000 cps under similar conditions

The above recommendations indicate that noise has a differential effect upon various frequencies, with the higher tonal levels being more readily affected The suggested maximum sound levels can be interpreted more readily in terms of everyday experience with the help of Bonvallet's (1952) estimate that the sound pressure level of the average living room is 40 db, a typical office, 60 db, street corner traffic in a large city, 75 db, and the inside noise level of a large passenger airplane (DC 6), 104 db

In view of the progressively adverse effects of noise upon auditory acuity, more than comfort and ease of communication

are at stake in the attempt to control noise Various methods of control are recommended, including the reduction of noise at the source, the installation of shields and baffles, and, finally, the wearing of ear protectors when other methods fail (*Kryter, 1950, Murrell, 1957*)

AGING AND THE THERMAL ENVIRONMENT

Observation of older people leads us to expect that age changes take place in the ability to withstand extremes of temperature Old people, more than the young, seem to seek warmth and to complain both about severe cold and summer heat While

fully the tolerances of the aging and the aged for changes in thermal conditions and the nature of the basic mechanisms upon which these changes depend Nevertheless, substantial systematic work has been carried out, and approaches to the fundamental problems have been made

MEASUREMENT OF THERMAL CONDITIONS

It has long been known that the measurement of ambient temperature is insufficiently correlated with the subjective feeling of cold or warmth to be a reliable indicator of the thermal environment (*Yaglou, 1927, Bedford, 1953*) This is because thermal experience depends upon three additional factors in the physical environment—humidity, air movement and radiation from surfaces in the surroundings In addition to these environmental factors, temperature experience is dependent upon the balance of heat production and heat loss of the body While the former is a function of body metabolism, the latter is dependent upon radiation and convection of heat from the body and upon evaporation from the surface of the body and the lungs Body temperature and temperature experience are dependent upon the interaction of all these factors, and, as a consequence, the development of satisfactory indexes of environmental conditions affecting thermal comfort has proved troublesome Nevertheless, several reasonably adequate measurement systems have been devised These are the kata therometer, the *equivalent temperature*, and the *effective* temperature (Yaglou, 1927, Newburgh, 1949, Bedford, 1953)

The *kata therometer* as originally developed by Hill provided a measurement of the 'cooling power' of the environment This is accomplished by taking the time it takes the instrument to drop from 100° F to 95° F and calculating the "cooling power" from this, using a factor which is specific for the instrument By means of various modifications the effects of radiation convection, humidity, air speed and air temperature can be measured (*Newburgh 1949, Bedford 1953*)

Dufton has developed a scale of *equivalent temperature* which can be measured by means of an instrument he devised and called the "eupatheoscope ' Bedford (1953) states that readings from the equivalent temperature scale correlate 'well with subjective impressions of warmth," although he points out that since it does not take humidity into account, it is not useful at high temperatures

The *effective temperature* scale is believed by its originators to have certain advantages over the kata therometer and the equivalent temperature scale, although Bedford notes that the scale does not take into account specifically the effects of environmental radiation Yaglou (1927) defines this scale as "an arbitrary index of the sensation of warmth experienced as the result of temperature humidity, and air motion " The scale is based upon the assumption that any given degree of the experience of warmth can be brought about by a very large number of combinations of temperature, humidity, and air movement If the dry bulb and the wet bulb temperature and the air movement are known, a scale of the subjective feeling of warmth can be constructed based upon these three

objective measurements However, since the subjective thermal experiences are based upon body heat production and loss as well as upon environmental conditions different scales of effective temperature must be constructed for different bodily conditions Important factors in this respect are the activity of the individual and the amount of clothing worn Accordingly two scales were developed originally the basic scale for individuals stripped to the waist and the *normal* scale for lightly clothed individuals Both scales apply only to individuals who either are inactive or are doing very light work

The value of this scale in describing thermal environmental conditions is obvious but unfortunately it has not as yet been exploited for the study of age changes in response to objective thermal conditions Some research findings based upon effective temperature measurements are nevertheless pertinent to this discussion For example Yaglou reports that conditions of maximum comfort for people wearing normal winter weight indoor clothing are represented by an effective temperature of 66° While many different combinations of dry and wet bulb temperatures and air velocities could produce this degree of effective temperature for the sake of illustration we could obtain it with a wet bulb temperature of 70° F a dry bulb temperature of 58° F and zero air velocity On the other hand a dry bulb temperature reading of 76° F a wet bulb temperature of 56° F and an air velocity of 200 feet per minute also yields an effective temperature of 66° and therefore should be equally comfortable as far as warmth is concerned (Yaglou 1927)

PHYSIOLOGICAL EFFECTS OF THERMAL CONDITIONS

Certain physiological reactions follow closely the effective temperature scale until it reaches approximately 90° At this point further increase in effective temperature is accompanied by accelerated physiological response In arriving at this generalization, Yaglou (1927) observed changes in pulse rate in body and skin temperature and in metabolic rate In each of these measures acceleration became apparent with remarkable consistency at about 90° effective temperature Yaglou therefore believes that this temperature represents the maximum for which the individual can compensate without undue stress In hard manual labor 80° effective temperature is the maximum set by this investigator

Machle (1946) on the other hand is reluctant to set the precise limits of thermal conditions He states that there are no general arbitrary environmental standards that can be established with confidence Individual maxima are imposed by a number of factors both environmental and physiological and prominent among these is the factor of age Referring primarily to thermal working conditions he states that limits can be set only by observing the worker for signs of heat exhaustion which in the final analysis are largely behavioral Rectal temperatures for example are for the most part unreliable for this purpose although they undeniably reflect internal body temperature Men can and do work with rectal temperatures of 103° F but others may succumb to heat exhaustion with no rise in rectal temperature

Machle emphasizes age as an important factor in the tolerance of temperature stress Individuals between the ages of 21 and 28 years are best able to withstand the effects of hard work at high temperatures those between 18 and 21 years are less able to stand such rigorous conditions and for those above 28 years this capacity seems to fall off sharply

In addition to age the ability to do hard physical work in hot environments depends upon physical condition Loss of rest intercurrent infection alcoholic indulgence dehydration and inadequate caloric or salt intake all are detrimental influences Particularly interesting is the reported finding that a loss of 1 5 per cent of body weight

by water deficit is subjectively equivalent to a rise in air temperature of 12° F (Machle, 1946) Added to this is the fact that thirst is an inadequate indicator of the water needs of the body and that as a result, men working in great heat commonly tend to drink insufficient quantities of water for their requirements

The oft repeated warnings against drinking cold water in hot environments cannot be substantiated scientifically, in fact, best water temperatures range between 45° and 50° F, both for refreshment and for concealing the taste of salt when it is added to the water In order to replace the body salts lost by rapid and excess perspiration water should be salted in amounts equivalent to 0 1–0 15 per cent of the weight of the water The salt intake in the normal diet is however sufficient for the less severe heat stresses Machle reports no differences in ability to withstand heat stresses with either high or low protein diets Nor does he find a high carbohydrate diet to be of any particular advantage

Specific studies to determine the physiological effects of temperature stress in old age have been carried out by Krag and Kountz (1950, 1952) and by Horvath *et al* (1955) The former investigators studied the effects of exposure of the body to cold in thirteen elderly subjects ranging in age between 57 and 91 years and six younger subjects aged 22 36 They concluded from their investigation that the increase in oxygen consumption under the experimental conditions was greater in the old subjects but that these subjects were less effective in the prevention of heat loss This finding is contrary to Cannon's supposition that the reason for age related diminution in capacity to withstand cold lies in the elderly subjects' reduced basal heat production (Horvath *et al*, 1955)

Horvath and his associates however, find support for Cannon in a similar study of eight older persons (ages 52–76) and seven younger individuals (22–27 years) He rejects Krag and Kountz s conclusion that the mechanism for control of heat loss is less efficient in the elderly More study is needed to clarify this point In summary Horvath says "No statistically significant changes in minute volume, oxygen consumption, respiratory quotient, and heat production were observed as a consequence of their [the older subjects] being moved from a comfortable to a cold environment This is in marked contrast to the large increases found when young adults were similarly stressed' (p 148)

Both studies agree on the reactions of the older persons to the experience of cold during the experimental period In neither study did the elderly group complain of the cold, whereas the young subjects were wont to express keen feelings of discomfort In the Krag study some of the young subjects complained of feeling chilly during the remainder of the experimental day, none of the older ones was so affected This difference in experience does not appear artifactual for it correlated well with the observed differences in occurrence of shivering Only one of Horvath s older subjects shivered during exposure and in this individual the reaction was mild and occurred after 31 minutes of exposure All the younger subjects shivered after a period of exposure ranging from 2 7 to 23 2 minutes

Since shivering is considered one of the bodily mechanisms to protect against heat loss it would appear that the inability of the elderly to maintain body heat as efficiently as young people is reflected, although not limited by the increased threshold of this response No suggestion is given to explain this difference, so we are free to speculate on possible relationships with age changes in sensory thresholds to cold, perceptual and central changes, and perhaps even motor changes In any event, the phenomenon is of sufficient interest and importance to warrant further intensive study

Krag and Kountz (1952) also studied the effect of heat exposure on the stability of body function in the aged Fourteen subjects aged 57–95 years and twelve subjects 21–32 years old were exposed to ambient

temperatures of 100°–115° F for periods ranging up to 90 minutes The older subjects stood these conditions fairly well, although their measured physiological reactions were more varied than young subjects Part of this variability of the aged subjects can be attributed to the marked debilitation of some of these individuals Thus in the young group the correlation (r) between rectal temperature and pulse rate was 0 84 in the older group, 0.72 With the removal of debilitated subjects from the older group however the latter correlation rose to 0 82 while that for the debilitated aged alone dropped to 0 45 This lack of close relationship between these two variables in the debilitated group suggests a failure of the physiological mechanisms for stabilizing body temperature which in turn suggests the dependence of body temperature mechanisms upon physical condition rather than upon age alone

AGE ACCLIMATIZATION AND CLOTHING

That acclimatization occurs is popularly accepted as a physiological fact yet supporting evidence is not obvious Does one adapt physiologically to winter temperatures or simply begin to wear more suitable clothing? Similarly do basic changes occur in body heat processes with long exposure to tropical temperatures or does one simply change one s way of life so as to reduce the generation of body heat and to hasten its loss? Finally if acclimatization can be said to occur does age influence the adaptability of the organism to temperature change? Answers to these questions are not easy, nor are they entirely satisfactory but relevant data are at hand (Newburgh 1949)

Comfortable ranges of indoor temperatures are undoubtedly influenced by both clothing and acclimatization Although the exact nature of this interaction is unknown Yaglou (1927) has investigated the relationship His results indicate that the preferred temperature for a group of normally clothed adults (American) at rest or performing sedentary tasks was a dry bulb temperature of 70° F In order to achieve equal comfort without clothing (i e, stripped to the waist), the temperatures had to be increased to 80° F Similarly, the upper limits of uncomfortable cold for the two conditions of dress were 62 3° F and 72° F and for the feeling of being too warm the threshold limits would be, respectively 80° F and 91 8° F In other studies Yaglou found that when dressed appropriately for the season subjects preferred an optimum temperature in summer that was about 6° higher than their winter preferences This he attributes more to the lighter summer clothing than to acclimatization. It would be most interesting to know if these limits tended to change with age as well as the way in which preferences for certain weights of clothing would relate to possible changes in thresholds of the comfort zone

Machle (1946) believes that acclimatization is a significant factor in individual adaptation to work and activity in high temperatures With exposure to heat, he says the body temperature rises until a new level of equilibrium is reached These levels may be as high as 103° F rectal temperature They may change with time and tend to be reduced with acclimatization The process of acclimatization starts immediately upon exposure to heat and continues rapidly for 2 or 3 days and more slowly thereafter for an additional 1–2 weeks The speed and effectiveness of the process depend upon the physical condition of the individual Bazett (1949) believes that complete temperature adaption takes longer He says that ' acclimatization to warmth is mainly accomplished during the first week, but like that to cold it is probably not completed for months '

Grad and Kral (1957) provide some interesting observations from animal work on the effects of age upon the process of acclimatization These investigators report a higher mortality rate among old mice than in young mice when both are exposed to equally cold environments A reduction in

environmental temperature from 26°–27 C to 4° C in the space of 1–2 hours killed all the old mice When the temperature was reduced slowly over a period of a week all the older animals survived for at least 24 hours in the low temperature that previously proved fatal However all the young mice survived for a week in the 2°–4° C, but only one third of the older group lived out the period This study is a somewhat dramatic demonstration of the survival value of acclimatization Clearly the *older mice could adapt if given time to the* low temperatures but in this they were not so efficient as the younger animals

While the above studies and observations tend to support the existence of acclimatization and physiological fact Ellis (1953) contends that the adaptation to new climatic conditions depends upon a complex of factors which cannot be duplicated exactly in the laboratory Referring specifically to the problem of tropical fatigue a somewhat ill defined pathological condition of depression and ennui he says It is the cultural problem of *learning to live in the* way which is most suitable to the tropics and the economic situation of the individual ' Undoubtedly this observation has general significance and could be applied to any profound and relatively permanent environmental change which involves adaptation not only to a new climate but to altered social economic and physical conditions as well Since many older persons do upon retirement seek the presumed benefits of warmer climates far from their usual social and cultural milieu Ellis observations on *tropical fatigue* are germane to this discussion

Unfortunately he offers no simple yardstick to measure the likelihood of good adjustment to profound changes in climatic conditions Except for the extremely debilitated the only way to find those who will adjust suitably is for them to go and try Ellis suggests that there are fairly wide individual differences in ability to adjust *comfortably* to warmth and cold *which* probably have some physiological basis but [illegible] s of such people have not been [illegible] in other than the most general qualitative terms We shall see however, in the section on ' Excessive Temperature and Mortality presented below that those who live in warmer climates experience lower death rates during extremely hot weather than do populations of cooler regions This fact is *apparently further evidence that acclimatization* does occur and does play a significant part in our lives

AGE THERMAL CONDITIONS AND ACCIDENTS

One general indicator of the effectiveness of adjustment to various environmental conditions is obtained from a study of accident records The relationships between age and accident frequency and severity is well documented (Viteles 1932 *Johnson 1946* Kossoris 1948 Kleemeier 1954 Van Zelst 1954) While age curves differ according to type of accident and to accident severity a *frequent finding in in*dustry is a diminution of accident rate with age as well as with experience on the job In certain instances frequencies rise during the later working years and certain kinds of accidents (non industrial) rise markedly in old age One additional factor known to influence accident rate is environmental temperature

Vernon and Bedford (1927) have shown that both high and low temperatures are associated with increased accident frequencies They found that in munitions factories accident rates were at a minimum when ambient temperature was 65°–69° F At temperatures over 75° F however, rates were 23 per cent higher and below 55° F they were increased by more than 30 per cent Vernon and Bedford (1927) show that both accident frequency and severity rates decrease among certain groups of miners as the wet kata cooling power of the mine atmosphere increases

Most interesting for our purposes however is the interaction of age and tempera

ture upon accident rates This is demonstrated in Figure 8 which shows the relative accident frequency of miners working on coal faces in relation to age and temperature (Vernon *et al* 1931) It will be noted from this graph that in temperatures under 70° F in which there was no thermal stress the lowest accident frequency was earned by men aged 40–50 years In those mines however, with ambient temperatures above 70° F accident frequencies rose sharply after the age of 40 The investigators attribute this increase in accidents in the older groups to lessened ability to withstand the greatly augmented fa

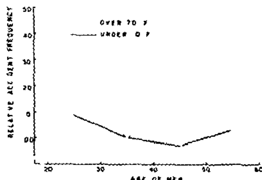


FIG 8 —Relative accident frequency of coal face workers in relation to age and temperature (After Vernon *et al* 1931 p 108)

tigue effects brought on by the high working temperatures They go on to point out that the recorded accident frequencies under these adverse thermal conditions are not exactly comparable with those normally encountered Men who incurred minor accidents at high temperatures 'claimed accident compensation three or four times more frequently than men incurring minor accidents at lower temperatures ' This is attributed to a disinclination to work at the higher temperatures because of the more fatiguing and unpleasant conditions

EXCESSIVE TEMPERATURE AND MORTALITY

If, as it appears, the aged have diminished abilities to withstand excessive temperatures then we should expect this to be reflected in age related mortality rates during the periods of excessive temperatures characteristic of summer heat waves These expectations are borne out by the findings of Shattuck and Hilferty (1932, 1933) and to some extent by those of Gover (1938) The latter while not specifically interested in age relationships demonstrates unmistakably the influence of peak summer temperatures upon increases in death rate

Gover finds that during the summer months weekly mortality rates for particular localities jump to as much as four times the expected rate for this season of the year That these increases are clearly due to excessive temperature can be demonstrated by comparing weekly death rates with daily temperatures for the entire summer period Such comparisons show that peaks in death rates usually follow the temperature peaks by several days to about a week In making these comparisons Gover feels that a more accurate picture of heat effects is obtained if death rates from all causes are used rather than limiting the analysis to those deaths in which heat is certified as either a primary or a secondary cause Since in fact these remarkable increases in death rate are temporally associated with extreme temperatures it is reasonable to assume that heat waves prove fatal to many individuals suffering from a variety of debilitating conditions yet whose deaths cannot be attributed to either heat stroke or heat exhaustion the two generally recognized heat responses This is further confirmed by the fact that the sharp rise in mortality rate occurs generally only with the first heat wave of the season with only slight rises accompanying successive hot spells Thus it seems that those who are already in a weakened condition fail to live through the initial period of excessive heat but the survivors are as a group better able to withstand subsequent hot weather

Shattuck and Hilferty (1933) have demonstrated differential age susceptibility in mortality to excessive temperatures They report that heat death rates are high dur

ing the first year of life, are quite low until age 20, rise gradually until age 70, and increase sharply thereafter As can be seen in Table 6, the death rate for males between the ages of 20 and 60 is found to be considerably higher than for females This is attributed by the authors to adverse temperature factors related to conditions of employment Since these data were gathered early in the century, when conditions of work were undoubtedly less favorable than those of the present, this hypothesis could be tested by an analysis of current data Presumably, the sex difference in *heat related mortality would be reduced, if* this environmental interpretation is to be substantiated

Also to be seen in Table 6 is the relatively high heat death rate in Boston as compared to the rest of Massachusetts While not strictly an urban rural comparison, it certainly is essentially that and, as such, tends to support the authors' contention that conditions of housing, clothing and habits of living and working are all contributors to this rather substantial difference in rate

Gover shows that several consecutive days of extreme temperature have more effect upon mortality than do periods of variable temperatures, even though some extremely hot weather may be experienced during the variable period In each of the years selected for study the maximum death rate occurred in the week following a period in which an average daily maximum of at least 95° F was reached for more than three consecutive days Small deviations in temperature are not reflected in the mortality rates but very high temperatures for sustained periods are associated with markedly excessive mortality

Regional variations in mortality experience support the case for acclimatization referred to above Although the highest mean temperatures occurred in southern areas of the United States, the largest mortality excesses were reported in the North Atlantic and North Central regions It is significant, however, that the northern deviations from normal temperatures were greater than those occurring in the South, although in the latter region actual mean temperature levels were higher In view of this finding Gover concludes

> It is therefore, the excess in temperature rather than the actual temperature which is associated with a marked increase in weekly mortality when all sections of the country are considered This suggests that acclimatization is a factor in response to temperature [1938, pp 1131–32]

TABLE 6*

DEATH RATES (PER 100 000) FROM PRIMARY SUNSTROKE AND DEATH RATES IN WHICH HEAT EFFECTS WERE SECONDARY CAUSES, BY AGE AND SEX FOR BOSTON AND REMAINDER OF MASSACHUSETTS JULY, 1911

AGE	BOSTON		REMAINDER OF MASSACHUSETTS	
	Male	Female	Male	Female
	Primary Sunstroke			
20–59	55	9	11	2
60 and over	140	44	33	21
All ages	41	11	9	4
	Heat Effects Secondary			
Under 20	10	13	6	8
20–59	16	6	6	4
60 and over	95	143	73	68

* Source Shattuck and Hilferty (1933)

Elsewhere in her paper Gover presents evidence indicating that January mortality rates are somewhat more than 2 per 1000 population greater than are selected normal rates for July This fact in itself suggests an adverse effect stemming from winter temperatures and weather conditions It would appear from the data that only during periods of very hot weather do July death rates approach or exceed those of the normal January The implication of this

the age of 75 this proportion is reduced to scarcely more than half This breakup of the independent household is accompanied by *increases in the proportions of this age* group residing in households other than their own and in various institutional set tings While the number of individuals liv ing in institutions appears to be small a for example, are frequently large Thus we learn from a special sample tabulation of the 1950 United States data that 44 per cent of *dwelling units in* which the head of the family was *under* the age of 65 the number of persons per room was 0 75 or more On the other hand, the dwelling units in the over 65 age group had a density of

TABLE 7*

PERCENTAGE DISTRIBUTION OF LIVING ARRANGEMENTS OF PERSONS AGED 65 YEARS AND OVER BY AGE AND SEX BASED ON A 3.3 PER CENT SAMPLE OF THE 1950 U S CENSUS

LIVING ARRANGEMENT†	AGE								
	65 and Over			65 74			75 and Over		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1 Total	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
2 Living in households	94 3	93 8	94 7	95 3	94 5	96 0	92 1	92 1	92 1
3 Own households	69 9	75 9	62 8	74 8	80 2	69 6	56 3	65 7	48 6
a) Married and living with spouse	43 9	58 5	31 1	51 1	64 5	38 9	28 3	44 7	14 8
b) Living with relatives other than spouse	10 6	7 1	13 6	10 0	6 2	13 3	11 8	8 8	14 4
c) Living alone or with non relatives	14 4	10 3	18 1	13 7	9 5	17 4	16 2	12 2	19 4
4 Not in own households	25 3	17 9	31 9	20 7	14 2	26 4	35 8	26 4	43 3
a) Living with relatives	21 1	13 5	28 0	16 5	9 9	22 4	31 3	21 7	39 0
b) Living with non relatives	4 2	4 4	3 9	4 2	4 3	4 0	4 5	4 7	4 3
5 Living in quasi households	5 7	6 2	5 3	4 7	5 5	4 0	7 9	7 9	7 9
a) In institutions	3 1	3 0	3 2	2 1	2 2	1 9	5 3	4 8	5 8
b) Other quasi households	2 6	3 2	2 1	2 6	3 3	2 1	2 6	3 1	2 1
6 Total	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0	100 0
7 In families (one or more relatives present)	6 5	79 9	73 4	8 4	81 6	75 6	72 2	76 1	68 9
8 Not in families (no relatives present)	23 5	20 1	26 6	21 6	18 4	24 4	27 8	23 9	31 1

* Source Ashley (1957) Table 4a p 18

† The terms household quasi household and family are used in this table as defined in 1950 by the Bureau of Census A household includes all persons who occupy a house, an apartment or other group of rooms or a room that constitutes a dwelling unit It includes both the related family members and unrelated persons A person living alone or a group of unrelated persons sharing a dwelling unit are counted as households Institutions transient hotels rooming houses trailer camps etc are considered quasi households

more discerning enumeration would un doubtedly show that many of the house holds in which the elderly person lives with *non relatives* have institutional character istics (Kleemeier 1956*b*)

These figures give us only indirect in formation concerning the physical environ ment in which the elderly reside From oth er census and survey data more details of the picture emerge (Ashley, 1957) Houses, over 0 75 person per room in only 18 per cent of the cases Although only 15 per cent of this sample of heads of households was *over the age of 65* they occupied 21 per cent of the seven room houses and 26 per cent of the eight room houses covered in the survey Houses of this size were occu pied by only about 6 per cent of the young er householders The inference that the eld erly person often occupies a dwelling unit

larger than necessary is substantially supported by these findings

Add to this the fact that the dwelling of the aged individual is frequently older and in poorer condition than that of younger people and it becomes easy to accept the generalization that it is also often too difficult and too costly for him to maintain and operate While such generalizations are dangerous and tend to ignore the great overlap with younger people in terms of housing as well as other characteristics of age it points to a situation occurring commonly enough to merit special attention

TABLE 8*

INVALIDS† PER 1000 POPULATION AND PERCENTAGE DISTRIBUTION BY AGE GROUP 1935–36 (U S NATIONAL HEALTH SURVEY)

Age Group	No per 1000 Persons	Percentage Distribution
All ages	11 7	100 0
Under 5	1 6	1 0
5–14	3 1	4 6
15–24	4 6	7 1
25–34	5 7	8 0
35–44	10 8	14 6
45 54	16 2	16 8
55–64	28 5	17 9
65 74	55 0	19 2
75–84	76 1	9 1
85 and over	101 0	1 9

* Source After Britten et al (1940) Table A p 92

† Persons disabled for the entire 12 months immediately preceding the date of interview

If much of the present housing of older people is unsatisfactory for their present and anticipated needs it follows that major attention must be paid to the possibilities of modifying present living quarters in order to meet minimum standards of adequacy in addition to the erection of new housing adapted to these specialized needs

Obviously older people who suffer no marked physical or mental impairment require no specialized housing apart from the consideration of economic and social factors Fortunately, these well aged are in the great majority Nevertheless the probability of serious infirmity increases markedly with age Inspection of Table 8 shows the acceleration of disability rates with increasing age while Table 9 suggests the extent of decrease in mobility suffered by disable older persons

These considerations support the contention that an important objective in environmental planning for older people is

TABLE 9*

MOBILITY STATUS OF RECIPIENTS OF AID TO PERMANENTLY AND TOTALLY DISABLED BY AGE GROUPS THIRTY STATES MID 1951

Mobility Status	No of Recipients	Percentage Distribution			
		All Ages	Under 35	35 54	55 and Over
Total recipients	99 359	100	9 9	36 4	53 7
Household total†	19 350	100	12 3	37 6	50 1
Bedridden	5 313	100	13 0	36 8	50 2
Chairfast	5 829	100	14 2	38 2	47 6
Other‡	8 208	100	10 5	37 8	51 7
All other recipients§	73 973	100	9 3	36 1	54 6

* Source U S Department of Health Education and Welfare (1955) Table C p 93

† Represents 20 7 per cent of all recipients of aid to the permanently and totally disabled

‡ Capable of moving about within their homes but not outside

§ Capable of activity outside the home or usual residence

the achievement of maximum adaptability of living quarters in order to meet the contingencies of possible infirmities (Vivrett, 1957) Patently, in this connection much can be accomplished by modifying existing dwellings when the need arises The practicality of this suggestion has been demonstrated effectively by Warren (1957), who shows the way in which the occupational therapist and the architect can combine forces to meet the environmental needs of the aged disabled person through helpful modifications within the individual's own home This approach requires that each case be treated as an individual problem in which an attempt is made to minimize the effects of physical limitations by appropriate environmental modification

For Mrs A whose heart condition and poorly healed left hip seriously interfered with her ability to live independently it meant several structural changes in her apartment The cutting of a new doorway from bedroom to bathroom made the bathroom much more accessible Other modificatons all designed to allow Mrs A to continue living in her own home included installation of strong grab bars by the bath tub remodeling of work surfaces and cupboards with special attention to height and convenience and an inexpensive modification of the heating system to provide central heating Further recommendations were made concerning Mrs A's activities in order to increase her range of interests and satisfaction with life [Warren 1957 p 234]

SPACE ORGANIZATION

Opinions differ widely concerning the uniqueness of the environmental needs of the elderly Certainly living quarters ideally suited to the aged household should prove equally well adapted to the needs of a younger family of the same size (Scottish Housing Advisory Committee, 1952) Even the presence of children would make little fundamental difference However, the reverse need not be true The young family is capable of living well in challenging circumstances too rigorous for the diminished energies of the elderly couple Unquestionably, some of the infirmities of age require environmental adaptations Most of these will be directed toward the reduction of energy expenditure, maintenance and control of temperature and humidity levels, and adaptation of the tools for good and healthful living to the limited capabilities of infirm persons

It is not likely that more than the establishment of certain broad generalizations can be hoped for in this area Specific solutions to certain technological problem can, however emerge in great abundance The more of these the better Advances in home heating lighting, plumbing, furnishings and utensils will continue In the development of these the overriding aim of greater convenience and ease of living for the general public is not incompatible with the needs of the aged

Demands for sound advice in the construction of dwelling units for the aged has been met with published suggestions and check lists for architects and planners but practically none of these is sufficiently based upon sound research or experience to be accepted with great confidence, even though the ideas they contain may ultimately prove of great merit Special attention has been given to home-management aids Research into problems the handicapped man and woman meets in doing ordinary household tasks and attempts to develop techniques, self help devices, and gadgets have had useful results, many of which could be applied to the benefit of the aged (Rusk and Taylor, 1953) Motion study and job simplification techniques have been applied to homemaking (American Heart Association 1950, Huff, 1954, Gilbreth *et al*, 1955), but the tangible results of these small efforts have not been impressive

One of the more satisfying research-based recommendations for the housing of older people is contained in a report by the Scottish Housing Advisory Committee (1952) These recommendations resulted from actual experience with public housing for the aged, an extensive social survey,

visits to many housing schemes in Scotland and England, and consultations with various local housing authorities and interested organizations While certain of their recommendations have only regional or limited significance, much of the material covered in this report is widely applicable

An important feature of the Scottish investigation was a survey conducted in the burgh of Hamilton in September, 1950, in which a random sample of 868 people (419 men and 449 women) aged 60 years and over was interviewed Two objectives of the inquiries were to obtain information concerning the size of households of elderly people and the kinds of difficulties they encounter in performing essential household tasks

While some 9 per cent of the older people of Hamilton were living in houses considered to be embarrassingly large for them, it by no means followed that older people had no use for other than the smallest of accommodations About one half of the households in which the elderly of Hamilton lived were composed of three or more people, and in approximately 80 per cent of these the head of the household was 60 years of age or older Because of the range in size of households, the committee could see no way of solving the problem of dwelling size for older people in public housing except by arbitrarily limiting the 'specialized" units to the one and two person households For the larger households they recommended that careful attention be paid to the needs of the elderly tenant, particularly the housewife In some instances it was thought that the larger housing units could be modified to lighten the load of household chores

The extent to which disability must be considered as a factor in housing the aged was revealed by questions covering ability to dress and bathe, to climb stairs, to walk reasonably far distances, to use public transport, and to carry out ordinary household duties Eighty five per cent of the sample reported having no difficulty with dressing and bathing, but only 65 per cent indicated that climbing stairs offered no trouble In both these activities women report more difficulties than do men, and, as age increases beyond 60, increasing proportions of the sample report problems At age 60–64, for example, 95 per cent of the men and 90 per cent of the women are able to bathe and dress themselves adequately and without assistance, but in the group over the age of 80 these percentages fall to 83 per cent and 61 per cent, respectively Of the 60 year old men, 80 per cent are able to climb stairs relatively easily, but only 61 per cent of the women of this age make this claim Over the age of 80 these percentages have been reduced to 59 per cent for the men and to a mere 22 per cent for the women

A similar picture obtains with reference to walking and to using public transportation Sixteen per cent of the sample claim that they are unable to walk a half mile Again the women are markedly poorer than the men, with 25 per cent unable to walk this distance as opposed to 7 per cent of the men Even granting a male tendency to exaggerate his physical prowess, the difference is interestingly large More men than women, likewise, were able to use busses, the respective percentages being 83 and 70 As might be expected, however, fewer women than men reported they would have difficulties in cleaning the house, cooking, and washing the clothes, although these differences are not marked and might not be significant statistically Grouping both sexes together, we find that no difficulty is experienced or anticipated by 63 per cent in cleaning the house, 75 per cent in cooking 53 per cent in washing clothes, 78 per cent in looking after fires, and 69 per cent in shopping

Consideration of these survey facts supported the contention that specialized units should be provided for the one and two-person households of older people and that these should be designed for the kind of easy maintenance and healthful surroundings required for the aged Rejecting the arguments that the demand was uncertain

and the special provisions too costly the committee felt that there was no reason to limit such accommodations to the aged By allowing younger stable small family groups to occupy these units the stigma of age segregation could be avoided and at the same time maximum occupancy of the units could be assured

The Hamilton survey showed that about 20 per cent of the sample of the households containing older people wished to move This percentage is almost identical to the findings of Hunter and Maurice in an American community but it is considerably less than the expressed desire (60 per cent) of the sample of another British community (Kleemeier 1956*b*) When asked where they would like to live 44 per cent of those wishing to move wanted to be rehoused in the same neighborhood another 19 per cent wanted to remain in Hamilton and only 9 per cent wanted to leave the community The remainder had no marked preference Most of those desiring to move wanted to go to an independent bungalow (79 per cent) rather than to a flat or an apartment or even to a group of independent bungalows looked after by a supervisor (45 per cent) Flats at their best were less preferred than the independent small house Forty two per cent were willing to live in a small two- or three story block of flats but if the flats were in a large building requiring the use of an elevator or lift the percentage dropped to 32 and if the flat was under the supervision of an individual charged with the welfare of the resident the percentage finding this acceptable fell to 24 As might be expected from his reaction other less-independent arrangements were clearly unacceptable except to a small minority These included lodgings (2 per cent willing to accept) bed sitting room in a hostel (13 per cent) private hotel (2 per cent) bedroom only in a hostel (4 per cent) and shared bedroom in a hostel (1 per cent)

It should be noted in this connection that although the bungalow was the most preferred accommodation for those households wanting to move (79 per cent), a clear distinction existed between the preferences of the single person households and those consisting of two or more persons Specifically only 50 per cent of the one person households were willing to live in bungalows but 96 per cent of the two-person households and 90 per cent of the larger family groups expressed such willingness

Unsupported statements are often made about the willingness of older people to live in the neighborhood of younger families and children In the Hamilton survey of those older people who wished to move only 4 per cent expressed unwillingness to live among younger people who had no children but 20 per cent did object to children in their neighborhoods Curiously the relatively small group of objectors is predominantly represented in the age group 60–69 While 60 per cent of the sample under the age of 70 had no objection to young neighbors with or without children 84 per cent of the over 70 s expressed such toleration Perhaps toleration however is a less adequate interpretation of these results than the hypothesis that the older respondents in their diminishing strength felt greater security in the nearness of younger people This too might explain why the preference for neighbors of the person s own age fell from 30 per cent in the under 70 s to 10 per cent in the older group

Again the committee finds in this result further support for their recommendation against prominent segregation of older people s housing units Rather they feel that careful distribution of these dwellings throughout the general housing areas might well encourage elderly people to pursue contacts with younger families and individuals Recognizing however that this arrangement is not equally suitable to the needs of all older people, they further propose that groups of dwellings be provided for those who need some outside attention Such groupings should not exceed thirty units and should accommodate both one- and two person households

Table 10 gives some indication of the preference of the Hamilton sample to live near certain types of facilities and services In general, age differences are not striking, and the nearness of shops appears to be the predominant requisite of the group, followed by the church, the parks, and the social center That care in siting should be taken to insure that these amenities are close by proposed dwelling units is, of course, obvious Nearness to public trans port is of equal if not greater necessity

TABLE 10*

PROPORTION OF OLDER PERSONS IN THE HAMILTON SURVEY CONSIDERING IT IMPORTANT TO HAVE CERTAIN AMENITIES NEAR THEIR NEW HOMES

	Amenity (Per Cent)					No of Older People Wishing To Move
	Shops	Cinema	Park	Church	Social Center	
Sex						
Male	8[illegible]	31	55	58	41	66
Female	93	30	44	72	33	102
Age group						
Up to 64 years	92	30	46	72	40	68
65–69 years	89	32	46	72	40	48
70 years and over	90	29	53	55	29	52

* Source Scottish Housing Advisory Committee (1952) Table 15

HOUSE PLAN, EQUIPMENT, AND FITTINGS

There are many regional, national, and even climatic differences which would make the promulgation of any general recom mendation concerning the interior plans of houses, their equipment, and fittings a very hazardous undertaking Some useful sug gestions, however, may be gleaned from the Scottish experience, even though the con text of this investigation is public housing for one regional group of British elderly people Nowhere is the regional characteristic of the Hamilton group more clearly expressed than in their overwhelming preference for the open fire as a major source of heat (94 per cent) and the rejection of central heating (only 16 per cent prepared to accept) While comparable figures are not available for the United States, central heating undoubtedly would be rejected by only a very small majority Nolan found, for example, in a survey of over four hundred Pennsylvania farm families that 97 per cent wanted central heating (furnaces), although only 46 per cent had this facility If these families were to have new houses, 82 per cent wanted heat in all rooms A little less than half (47 per cent) wanted fireplaces in new houses (Nolan *et al*, 1950)

In spite of these obvious limitations, in a field so dependent upon empirical research, experience and surveys are likely to remain the only substantial guides for some time to come For example, logical considerations led to the development of the so called "open bedroom" in one of the house types recommended by the Scottish committee This bedroom was an independ ently lighted recess (80 square feet), separated from the main living room by a curtain Lower costs and ease of heating or more properly ease of maintaining a more nearly constant day and night temperature were in its favor However, only 14 per cent of the surveyed older households wish-

ing to move wanted this type of accommodation and most of those favorable were one person households (37 per cent of these) with only 8 per cent of the two-or more person households expressing approval Local housing officials and tenants were equally divided in favor of open bedrooms and separate bedrooms Such findings as these emphasize again the individual nature of housing preferences and the variety required to satisfy the divergent wishes of people

Much attention has been given to the kitchen as the work center of the home but again universal solutions are not possible Vivrett (1957) has emphasized the functional integration of the kitchen and the din ng room and the accessibility of cabinets Gilbreth *et al* (1955) and Huff (1954) the application of work study methods to household and kitchen tasks and the Scottish report (1952) the necessity of small kitchens for the single person households Although the latter study recommends and gives the actual design of a work saving kitchen in an area of 40–50 square feet it lacks universal appeal because it reflects a regional pattern of living Nevertheless the principle of smallness and compactness sets an objective which should have general relevance

The bathroom is another area in the house which has particular significance for old age planning The aged person is likely to falter in his personal hygiene especially if awkward fittings and arrangements exert him unreasonably and appear dangerous to use Vivrett believes most bathrooms to be too small and suggests that they should be large enough to accommodate a wheel chair should the occupant require it Many types of bathtubs have been recommended to make them easier and less dangerous for the infirm person to use but the Scottish committee feels that none overcomes these difficulties sufficiently well to receive approval They in fact reject the tub altogether and advocate instead a modified shower arrangement The essential features of this unit are a telephone type spray with a cable so that the spray head can be held in the hand a wooden seat that can be folded back to the wall and out of the way, hand grips thermostatic control on the shower to prevent scalding and a non skid floor

Pictures of this equipment were given to the oldsters wishing to move and their opinions of it were elicited by the interviewers Although only 36 per cent of this sample were prepared to accept this type of equipment it was felt that this was surprisingly high when one takes into consideration that none of the group had had experience with showers of this sort Since there was a slightly greater proportion of women and older members of the sample to accept this arrangement it was felt that it tended to appeal to those who experienced some difficulties with bathing and could be expected to become more popular with actual use Where bathtubs must be used this group preferred either the sitz bath type or relatively short tubs with cutaway sides

GROUP LIVING

Group living is perhaps an attitude more than anything else Nevertheless the physical setting in which group living takes place has great influence upon the happy acceptance of this way of life There are many shades and varieties in terms both of social organization and of physical environment Social personal factors determine the unique and common needs which must be supplied by the living pattern physical factors designed to serve these needs act as a limiting framework within which the community or group functions

We are accustomed to think of the social personal needs which stimulate group living among the aged as being largely negative in nature Increasing physical frailty and decreasing economic strength comb ne to force the individual to forego the relative independence of younger years and to seek aid in some form of group or institutional living As the Hamilton survey clearly shows any premature relinquishing

of independence is strongly resisted Accommodations in flats or apartments, it will be remembered which were apparently quite satisfactory became less so when a supervisor or warden was to be placed in charge to look after the needs of the elderly residents However, when the need for such supervision actually exists acceptance of this way of life becomes much more general Under these circumstances group living is no longer a threat to independence but becomes a desirable way in which to increase the range of possible activities as well as comfort in living (Kleemeier 1956*b*)

But group living can have its positive

nomenon and the promise is that they will continue to grow in popularity (Burgess 1954 Webber 1957) Perhaps here too we should place those communities which have become popular with older people and to which they come in large numbers Often located in resort areas the activities and amusements offered first attract the individual as a holiday maker and later upon retirement as a permanent resident

In the community of the elderly anything emphasizing an unwished for segregation is considered undesirable Consequently it has been suggested that these congregate dwellings conform in architectural style to others in the neighborhood that they be built in the larger community of which they are a part rather than on the outskirts or in the too quiet rural setting and that quadrangles or other arrangements tending toward physical isolation be avoided While these generalizations may indeed be valid it is probable that grouped housing arrangements violating these principles in many cases operate successfully in spite of and perhaps even because of these peculiarities of physical arrangement Multiple influences mold the lives that are lived within the community, and the kind and quality of the physical setting must be considered in this context. This is not said to belittle these physical environmental influences but rather to indicate that the interaction of community settings and individual social psychological characteristics is exceedingly complex

Nevertheless arrangement of dwelling place undoubtedly exercises great influence over the kinds of community relationships which develop Little work of importance has been done as yet in investigating this aspect of group living arrangements among the elderly although significant studies have been carried out on various social psychological aspects of housing in general and various kinds of activities programs and services have been described in connection with group living for the aged Nevertheless in spite of a lack of a systematic approach in this particular sub area the bright promise that investigation holds here has been anticipated by the studies of Festinger *et al* (1950) Although their studies were confined to a housing project for married university students (veterans) there is little doubt that the findings have bearing on the specialized housing needs of the elderly For our purposes the most significant generalization to be derived from their study can be summarized in the following exerpts

> In a community of people who are homogeneous with respect to many of the factors which determine the development of friendships the physical factors arising from the arrangement of houses are major determinants of what friendships will develop and what social groupings will be formed [Festinger *et al* 1950 p 151]

This caution however is added

> We emphasize once more that where the community is heterogeneous one would expect the ecological factors to have considerably less weight than they do in communities where there is a high degree of homogeneity and common interest among the residents [*ibid* p 163]

These conclusions are supported by careful research and meticulous sociometric analysis Thus it was determined not only that the arrangement of the apartment buildings in the project did influence the

development of friendship groups but also that the relatively small distances between apartments in the same buildings were reflected in friendship formation Basically the data indicate that any factor of environment which tends to increase the possibilities of contact between people should in the absence of negative forces increase the probability of friendship formation

Contacts may be of two sorts (1) passive contact which is casual and not specifically sought out by either party and (2) active contact which is intentional and planned so that certain individuals can be brought together Of the two the latter is apparently by far the less frequent and little influenced by distance The former however is primarily influenced by ecological factors The closer together two individuals live the more likely are their chances of meeting Thus one is more likely to meet one s next door neighbor than the neighbor living two doors away

Whether friendships follow upon these passive contacts depend upon a host of other factors However the greater the proximity the greater the number of contacts and in turn the greater likelihood of the development of friendship Distance however must be thought of both as physical distance and as functional distance The latter is determined by the arrangement of houses the various pathways that serve the housing group the common entrances to buildings and similar design features Functional distance thus becomes as important as physical distance in determining the frequency of contact between residents and in fact can either enhance or nullify the effects of physical proximity

For example in apartment arrangements in which five apartments adjoined each other in a line with approximately 20 feet separating each doorway from the next the middle unit received the greatest number of sociometric choices from the residents presumably because it was actually located closer to all other apartments than was any other unit on the same floor Similarly, there was a tendency for each floor in a two-story building to give most of their choices to neighbors on the same floor However the residents of the middle flat on the upper floor received no more choices than their neighbors because the effects of proximity were altered by the stairways located at each end of the floor Use of these stairs apparently increased the number of contacts with the lower floor residents and thereby increased the number of sociometric choices for these residents particularly for those occupying end flats adjoining the stairs Similarly houses which faced the court or quadrangle received more choices than did those which faced the street although the latter were arranged physically as a part of the court In this case the mean number of choices received by all inner houses facing the court was 1 56 while the mean for end houses facing the street was 0 60

Unfortunately we do not have stud es of the ecological factors involved in the living arrangements of older people which are on par with those of Festinger and his associates on younger groups That such a systematic approach would be helpful cannot be denied and assuredly the results could immediately be put to use in the expanding building programs directed at the needs of this particular group This concern transcends the restricted demands of group living thought of as institutional or quasi institutional living for in the broadest community sense the essential problems of living are those of living in the group

VI Summary

The relationships among age environment and behavior can be discussed intelligently only if limits are set and even then some arbitrariness in the selection of material must be exercised The approach made to the study of these relationships in the present chapter is broad perhaps unusually so but even here the imposition of limits is apparent

In this discussion the view is advanced

that environment includes not only that which surrounds the individual but also, in a very real sense, the body itself, which may be invested by the person with all the objective qualities ordinarily associated with less intimately known space occupying objects If this premise is accepted, then the familiar age changes which occur in body size, structure, and appearance become germane to the study of the age-environment relationship Surprisingly, little gerontologic interest has been attached to the study of these changes but, as demonstrated early in the chapter, a substantial body of knowledge based solidly in research already exists in this field In addition, the attempts to modify the effects of age on body form, and thus maintain the youthful body image, merge with the study of age change to create an interesting applied facet of this area of environmental inquiry

Sensory changes, particularly in vision and audition, make new environmental situations to which the aging must adjust Therefore, for older individuals visual and auditory conditions must be modified in order to compensate for age acquired losses in these and other modalities In vision special attention must be paid to such factors as illumination, object size, contrast and color to provide the optimum environment for the aging eye

The auditory environment also can be improved better to accommodate the hearing characteristics of age Sound amplification both at the source and at the ear is commonly used to lessen the effects of hearing loss Problems of adaptation of the listener to these attempts at compensation particularly in the case of hearing aids forms an interesting segment of this field

Thermal and atmospheric conditions of the environment are not equally well tolerated by all age groups In general, the limits within which adaptation is possible become more and more circumscribed with advancing age This applies to reaction to extremes of heat and cold, to the complex of factors (air movement, humidity, and temperature) which combine to set the limits of the thermal conditions of weather, as well as to the tolerance of atmospheric pollution

Finally, consideration must be given to the many factors which influence the elderly person in his home and community The design of dwellings for the older person, while presenting problems not markedly different from the design or ordinary housing, can be greatly improved by taking into account the results of research already accomplished in this expanding interest area

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XIV

Work and Occupational Skills

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I Introduction

This chapter is concerned with the older person at work from the point of view of his performance The term "older worker" is used here as freely as it is in other literature on aging—there is still no common agreement as to what it describes Usually, the older worker is held to be one who has passed the age of 45 years yet later in this chapter the value of making judgments by functional rather than by chronological age is stressed The term 'older worker" must apparently remain ambiguous until it is possible to standardize estimates of physiological age and apply them to working populations It is also unfortunate, though apparently unavoidable, that this designation gives the impression of a special case or type, the "older worker," where very often the age of the individual is only incidental to the fact that he is a good, passable or poor worker

The changes with age which appear most likely to affect performance are briefly summarized later in the text This is followed by a general consideration of methods of matching older workers and their jobs Next, the actual performances of older people at work are considered, first, in industry in general and, second, in the specialized fields of air and highway transportation Since the difficulties of retraining older people are now beginning to receive attention, this increasingly important question is dealt with, here the problem of learning in the older years is considered in relation to industrial employment

Experience in industry during World War II has to a certain extent given status to the older worker When opportunities for employment are plentiful, the contribution that the older worker can make toward higher standards of living is obvious It remains to be seen, however, whether this enlightened attitude would prevail if the number of jobs available became more limited and if the older worker competed with his juniors It must be said that, while older people have shown in many occupations that they can do the job as well or even better than younger workers, higher insurance costs with age complicate the picture for employers who hire them In monetary matters employers are highly realistic, as, indeed, they must be to survive It remains to be shown whether utilizing the older worker in certain occupations is more costly to the employer than hiring younger workers If the older worker costs the firm more, the question arises as to whether this cost is compensated for by the advantages in loyalty, dependability, and other factors which most studies have shown older workers to possess The employment of older people is, of course, of inestimable value to themselves, the society in which they live, and the economy in general

Before considering the implications of aging with respect to employment, brief consideration will be given to the changing

patterns of employment and occupations in general

The main result of industrialization has been a redistribution of the labor force Once mainly agricultural, it is now distributed among other industries, mostly manufacturing, commerce, and transportation As Woytinsky and Woytinsky (1953) point out, in 1870 over half the labor force was engaged in agriculture, after World War II, in April, 1948, only a sixth were so employed Job opportunities and the pattern of employment are constantly changing and have changed considerably within the lifetime of many workers now approaching the older age groups In most industrial countries there has been a tendency to enter employment later and to leave it earlier—a tendency "toward limiting gainful work to the ages of about 17 or 19 through 64 years" Although there is a definite downward trend in the number of workers aged 65 and over who are employed, this trend has been exaggerated by other factors, such as changes in classification In 1958 only 3 million persons 65 and over—one in every five—were in the labor force

Industrialization has made it possible to concentrate on other than basic agricultural needs, and this has been its most far reaching effect The increasing use of machinery has meant more economic and rapid production While also putting some skilled craftsmen out of work one of the main changes which automation seems to have effected is the elimination and replacement of unskilled labor

The implications of automation for employment are by no means clear, and divergent views are held by capital and labor and by economists. For all workers it would theoretically necessitate the learning and exercise of skills more rewarding than manual labor This gradual upgrading of skills has been accented as one of the more constructive effects of automation (MacMillan, 1956)

Automation, however, means fewer workers—fewer men are needed for a particular job Although this problem may be partly solved by shorter working hours, it becomes difficult for any economy to so balance itself that unemployment does not become a crucial problem from time to time While automatic control closes many doors, it does however open others, especially in transportation and technology (e g , motormen and bus drivers, radio and radar technicians, etc This is especially true with regard to air transport, and one of the newest of occupations, that of the airline pilot, is considered in detail later in this chapter A realistic summary of the advantages and disadvantages of automation is given by MacMillan (1956) From the point of view of the employment of the older worker, one cannot generalize on the effects of automation In selected jobs it would probably allow him to remain employed longer in others, with more severe job demands, it would limit him

A recent study by Le Gros Clark and Dunne (1956) analyzes the employment of older people since 1921 From existing statistics the census data of 1921, 1931, and 1951 were used no suitable figures being available for 1941 Thirty two occupations are examined from the point of view of determining "what numbers of workers are physically able to continue in their various occupations beyond their mid sixties The effects of automation are not revealed in this study since a prior condition was that changes in each occupation were controlled (e g , minimal changes in the organization and performance of the work during the period studied)

The occupations selected include heavy-labor (coal face workers), active jobs, such as that of bus conductors, and more sedentary work, such as that of shop assistants and craftsmen—watchmakers, workers in precious metals, and makers of musical instruments Working on a *survival rate* which they defined as "the proportion of the men who reach their mid sixties in a given job [and] are physically capable of remaining on the same job into their late sixties, or even in some cases beyond,"

these workers tabulated their results (Table 1) Their conclusion is that the nature of the occupation is the most important determining factor

This table shows the expected result of a higher survival rate in the less physically

TABLE 1*

SURVIVAL RATES IN 32 OCCUPATIONS

Percentage Survival Rates	Occupation
75–85	Makers of watches and clocks
	Workers in precious metals
	Makers of musical instruments
65–75	Farmers
	Agricultural workers
	Foresters
	Carpenters
	Bricklayers
55–65	Surface workers (mines)
	Welders
	Makers of boots and shoes
	Plumbers
	Plasterers
	Bargemen
	Dockers
	Shop assistants
	Warehousemen
45–55	Miners below ground (not at coal face)
	Makers of bricks and pottery
	Makers of glass
	Smiths
	Platers
	Riveters
	Makers of cigars and cigarettes
	Cabinetmakers
	Compositors
35–45	Foundrymen
	Makers of paper
	Drivers of trams etc
	Drivers of self propelled vehicles
	Bus conductors
25–35	Constructional engineers
15 25	
5–15	Coal face workers
	Signalmen

* Source Le Gros Clark and Dunne (1956)

exacting employments and crafts There are, however, slight discrepancies which mirror the effects of other factors which militate against older workers (e g, change in job methods) For example, with foundrymen, the lower survival rate may indicate such changes The problem of finding work for older men who are fit for it but who are deprived of their jobs by custom and economics is a major one Where job demands become physically less severe, there will be more of them available A recent plea for such men has been made by Pressey (1958)

II Effects of Aging on Performance

The work an individual can do is limited by his abilities and capacities These in turn are affected by, among other things, the aging process The mature old man or woman is, however, the product of a lifetime of habits beliefs, understandings, and disciplines or lack of them, and the pattern of aging is always individual We must be careful in ascribing to age, as such, defects (or assets) which may be rooted in development An old person who is maladjusted for instance, may always have been so In the winnowing of old age the more basic components of the individual are underlined since old age is a great underliner Aging may make apparent traits which are already present and perhaps unsuspected There is then a danger in regarding age as a cause rather than as an accessory after the fact

The changes in physiological and psychological functions which are described here are dealt with exhaustively elsewhere (chaps iv v vi, vii, ix, xv, xvi, and xvii) But insofar as these changes are directly relevant to work performance and the maintenance of skilled activity, it is necessary to summarize them briefly before going on to consider the older person at work It is against this background of alteration that the older person grows in wisdom and judgment, thus relatively preserving until no longer capable, the capacity for skilled work Although most studies show an unrelieved picture of decline in capacities, it is well to remember that this constantly changing balance between physiological and psychological impairment, on the one hand, and increased experience,

wisdom, and judgment, on the other, occasionally results in actual improvement of capacities, especially in those functions which are of greatest importance in daily living

It should not be forgotten either, however, that there are great individual differences between people as they grow older Many of our generalizations on the aged have been made from samples at the lower or the upper limits of this difference, with perhaps a prejudice toward the former When any psychological trait is measured in groups which differ in age, numerous members of the oldest group will perform more effectively than the average of the youngest group, and many in the youngest group will be below the average in the oldest group Chronological age alone is thus an uncertain indication of functional ability Thus a concept of functional rather than chronological age is required (McFarland, 1953) Among many attempts to assess physiological age is that of Murray (1951), combining several criteria such as vision, hearing, blood pressure and muscle force

At present most of the information available in regard to aging is in terms of group averages Such values obscure the variation at any one age A significant assessment of functional age requires that individuals be evaluated against themselves as well, that is, in terms of the history of the processes under question within the individual as well as in groups The implications of this for the health status of older people are that the relationships between behavior and physiological status are not very close, and a wide latitude of possible adjustments should be assumed Age in itself should not be considered detrimental Every physician is aware that a physical impairment in one patient may produce invalidism, whereas another patient with a similar disability may make a satisfactory adjustment (Shock 1951) Also the changes which occur cannot be arbitrarily evaluated as good or bad but instead must be clearly understood in relation to the demands of specific jobs Prolongation of life may well involve a comparable extension of time in various abilities as well as an extension of the capacity to accept economic and social responsibilities

Thus, to utilize fully the older workers, it is necessary to make a continuous adjustment between their capacities and the requirements of their vocation The reclassification of older workers to jobs where they can perform efficiently and safely and the alteration of jobs so that age changes are of minor importance should be based on a knowledge of the capacities of the individual in relation to the critical psychological requirements of each task Other sections of this chapter consider the problems of matching older workers and their jobs and also of retraining the older worker to meet the requirements of specific jobs

The changes in sensory, motor, mental, and emotional functions which seem relevant to the employment of the older workers are summarized below

THE INFLUENCE OF AGING ON SENSORY FUNCTIONS

With aging, all the senses manifest changes to some degree or extent In such functions as smell, taste, vibratory sensation, and pain, the changes are usually of little significance and may even be advantageous in certain tasks In other areas, such as vision and hearing, the changes are often not extensive and frequently cause less interference with adjustment or industrial productivity than is generally supposed In some occupations, however, adequate vision and hearing are of special importance and even small changes must be taken into consideration, especially in the presence of pre existing handicaps

Vision —Sensory functions are discussed at length in chapter xv Only one example of a change which has considerable practical significance with regard to employment in certain occupations will be given This is the decline of night vision with age With increasing age there is a progres

sive loss of sensitivity to dim light under conditions of low illumination (Fig 1) In this connection it may be noted that two-thirds of the fatal accidents on the highway occur during periods of darkness or low illumination The rise in visual thresholds with age has been amply demonstrated by numerous workers (Birren and Shock, 1950 McFarland 1954) A study was made of this phenomenon under carefully controlled experimental conditions, a correlation of 895 was obtained between age and the dark adapted threshold an unusually high relationship In practical terms this finding indicates that, for a light to be barely detected at threshold levels, each increase of 13 years in age requires a doubling of the intensity of the the light (McFarland and Fisher 1955) Such facts may help to explain the difficulties persons over 55 or 60 may experience in driving or flying at night and may also be related indirectly to the age change in visual acuity already mentioned If an elderly man drives an automobile with a tinted windshield it is as though an optical wedge were before him, reducing the amount of light transmitted by approximately 30 per cent and thus adding to the limitation due to this age

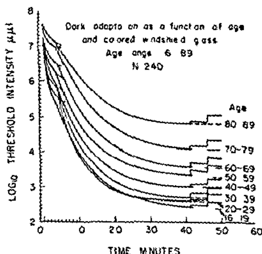


FIG 1 —The effects of colored windshield glass and age on final levels of dark adaptation on 240 subjects with an age range from 16 to 89 The effect of ordinary glass is shown by the first step at the lower end of the curves. The second represents the effect of colored glass (From McFarland *et al* 1959)

Hearing —With increasing age, the change in hearing in the average person is a well recognized phenomenon In general, there is a definite but relatively small decrease in sensitivity, chiefly confined to the upper frequencies (i e , 2000 cycles per second and over) (Fig 2) In a group of subjects chosen to represent a cross-section of the population between 20 and 60 years of age no significant deterioration with age was observed in the audiograms below 2048 cps Above this critical frequency, the loss became appreciable The median loss above 4096 cps was about 30 decibels for those from 40 to 60 years of age (Rosenblith and Stevens 1953) This question is fully discussed in chapter xv

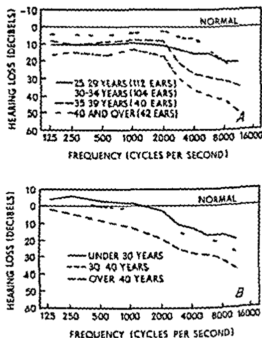


FIG 2 —The relation of age to auditory sensitivity Mean audiograms of 200 PAA and UAL pilots (*A*) and 449 AA pilots (*B*) indicate that their auditory sensitivity declines slowly with age especially for the higher frequencies (From McFarland 1953)

The practical implications of the loss of

auditory acuity that occurs with age relate chiefly to the effect upon conversation and communication, save for occasional occupational requirements for hearing certain high frequency sounds Consonants, particularly, will be less distinguishable, and the use of prosthetic devices to amplify the higher frequencies may be required to enable older persons to participate freely in conversation and social interchange The partially deaf old man is not so much a problem as the partially deaf old man who will not wear his hearing aid Moreover, the older person experiences relatively less difficulty in hearing in the presence of background noise, since there is less masking by the other sounds than is the case with normal hearing

It is interesting to translate these findings into the vocational situation as in airline pilots The regulatory agencies in the field of transportation at one time considered a new hearing standard which would have grounded many of the pilots In defense of the older pilots it was pointed out that some leniency should be permitted, namely, that older men with hearing losses tend to have fairly normal responses in the presence of aircraft noise This is a result of the 'recruitment" phenomenon Exposed to a noise of 40 db, one deaf pilot s hearing loss was reduced to 25 db masked with a noise of 60 db, his loss was only 15 db, and in a noise of 80 db his hearing was almost normal The basis for this phenomenon is difficult to explain, but one reason may be that low intensity signals are masked In fact, for loud intensities the person with marked hearing losses, as measured by an audiometer may actually hear quite well Older pilots with hearing losses therefore should be tested in simulated aircraft noise If the hearing losses do not interfere with the intelligibility of normal conversation or with aircraft signals in flight, safety will not be compromised (McFarland, 1953) The proposed new hearing standards were altered after the results of these studies were presented Close co-operation was obtained from the union when the members sincerely believed that the medical officers were interested in prolonging the useful flying careers of pilots

It is important to interpret the implications of aging in any sensory modality in relation to vocational adjustments Experience in this field requires a constant revision of earlier and possibly erroneous concepts Flying an airplane was originally believed to be an avocation or vocation of young men There are, however, more than a thousand private pilots over 60 who hold medical certificates with the Civil Aeronautics Administration It would have been unwise to ground such individuals for sensory defects, since their operating record has proved excellent. The important point is that age changes vary greatly from one person to another, both in nature and in extent An appraisal of a person s capabilities at any given period should include the amount of compensation present based on previous experience It is well known that compensation for declining functions can and usually does occur, so that the end results of behavior often show little change, and sometimes even improvement It thus becomes of great importance to establish the time when, in the normal process of aging, deterioration is no longer compensated for by prosthetic aids, past experience, or a change in methods (McFarland, 1953, 1954)

THE INFLUENCE OF AGING ON PSYCHOMOTOR FUNCTIONS AND SKILLS

Extensive studies of motor activity have revealed no sudden alterations in the speed of response from one age group to another There is a gradual rise in quickness of response in childhood and youth, followed by a slow decline in maturity However, individual differences at any age are great, and the average performance of a considerable number of older persons equals or exceeds that of individuals who are several decades younger (Miles, 1942)

Driving an automobile is a good example

of a complex skill that involves factors other than reaction time Three of its essential elements are steering co ordination, braking reaction time, and sensitivity to glare After 30–35 years each of these show a general decrease in ability with age It is noteworthy that the most complex skill which requires a high degree of eye hand co-ordination—steering co-ordination—declines more slowly than either glare vision or braking reaction time This difference may be interpreted as showing that a decline in skill may be retarded by age experience factors If ratings on several measures of driving ability are combined for a composite good driving score a general increase in competency with age is usually apparent (DeSilva 1938) There is no evidence that older persons are greater accident risks than younger ones in any form of transportation In fact the reverse is often the case (Lauer 1952 McFarland 1953 1954)

In the comprehensive study of aging at Cambridge University England deterioration in psychomotor skills and mental functions has been interpreted in terms of central nervous system receptor mechanisms In new situations the mechanisms concerned with organizing verbal or visual material operate less efficiently in the older person and require stronger "signals" or more time to relate the new data to relevant material in past experience Such changes may appear as early as 35 or 40 years of age (Welford 1958) If older persons are allowed to deal leisurely with incoming problems there is less likelihood of their becoming "muddled They should not be placed on jobs requiring continuous rapid action They are particularly well suited for operations which demand a high degree of accuracy since their deficiency in organizing new material is often more than offset by gains in quality and accuracy of performance once the material is assimilated This finding has important implications for driving an automobile or flying an airplane and for many skilled tasks in industry

THE INFLUENCE OF AGING ON MENTAL FUNCTIONS

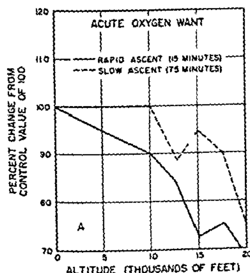
The influence of aging on mental functions is discussed in chapters xix and xx. It seems reasonable to conclude that the capacities of older workers are not clearly revealed by most standard tests now in use There are no reliable procedures to estimate such qualities as insight, judgment and reasoning which seem to increase in efficiency with age in many subjects Thus a great deal of work remains to be done on the mental capacities of older persons as related to various employments It is possible that many deficiencies now considered mainly in the field of sensation and perception may have many implications or ramifications in mental functions

Intelligence tests that are intended to measure innate mental capacity show less decline with age than those in which speed is a factor Consequently the capacity for comprehension reasoning and judgment appears to be maintained at a relatively constant level as long as mental work and intellectual interests are continued Older individuals with active minds can in many situations compensate for the decline of quickness in comprehension by means of the greater knowledge that comes with age.

The underlying physiological bases of the sensory and mental changes which occur in older persons relate to an interference of normal metabolic processes within the cells of the brain and central nervous system (McFarland 1952) This interference may operate through a reduced rate of transference of essential substances to the cells Transference may be inadequate because of reduced supply, reduced circulatory delivery, or slower diffusion Cortical tissue especially is extremely sensitive to a diminished supply of oxygen There is a striking resemblance between certain of the psychological changes which occur with age and the same functions in younger subjects who have been deprived of oxygen In one study for instance, immediate mem

ory was tested in various groups while at sea level and also at simulated altitudes Throughout the course of these experiments, each subject was required to memorize several series of ten pairs of unrelated words The influence of age was revealed by the fact that, whereas the average college student could remember approximately eight out of ten words their professors of about 55–60 years of age could recall on the average only four or five When the younger men were deprived of oxygen, however, their ability to remember was strikingly reduced, closely approximating the performance of their professors in normal air Thus the older man s decline in memory may be attributable to the influence of lowered oxygen in the cerebral circulation and of impaired brain metabolism in cortical functions (Fig 3)

The findings of other experiments also show that losses occur in night vision after oxygen deprivation, similar to those occurring with age (McFarland, 1953) A striking feature in normal subjects under low oxygen is a loss of insight into the quality of performance, parallel to that found in patients exhibiting abnormal social behavior and adjustment (McFarland, 1952)



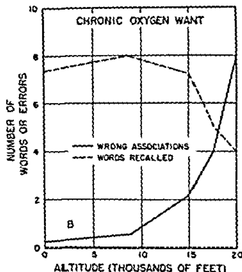


FIG 3 —Effect of oxygen want (altitude) on immediate memory The figure on the left indicates a significant decrement in objective tests for immediate memory at altitudes of about 10 000 feet or above during simulated flights. Impairment in words recalled and wrong associations was very marked above 15 000 feet in acclimated subjects on an Andean high altitude expedition (*right*) (From McFarland, 1953)

III Matching Older Workers and Their Jobs

When a worker's physical or emotional capacities are exceeded by the demands of his job, he is likely to injure himself or others and cause damage to property To prevent this happening at any given time, continual matching of the changing worker to the changing job is necessary throughout his working span

As Hanman (1947) has pointed out, it is not a great exaggeration to infer that the physically limited person is the average human being, and the fully able-bodied individual is the extreme " This physical limitation only becomes an occupational handicap, however, when it prevents one directly from taking on a specific occupation For instance, most of those reading this would be unlikely to qualify as test pilots or possess the capacities to stoke

blast furnaces but the deficiencies which would disqualify are not a handicap in their present occupations

Age in itself does not inevitably constitute a handicap Although it is clear that the reaction of the organism to aging is always highly individual some workers capacities are sufficiently limited by age changes as to increase their difficulties in meeting the demands of their jobs Insofar as this is so age may be considered a source of handicap Many are under the double handicap of age decrements and illness or injury The Office of Vocational Rehabilitation (OVR) has recently given priority in a special announcement on selected demonstration projects in vocational rehabilitation in eight areas one of which deals with the work evaluation of those who are thus doubly handicapped

Matching the older worker and his job however does not differ in any essential way from matching any other specific individual and job this is one of the advantages of the specific method evolved by Hanman (1947 1951 1956) which so far appears to be the most satisfactory procedure which has been developed The source of handicap is in selective placement irrelevant For instance a man suffering from a chronic illness and an aging worker may be equivalent in their surviving capacities but the *source* of their handicap is not of itself important in placement except insofar as it defines what their surviving abilities are This constructive attitude toward placement and capacity is gradually becoming more widespread. Placement is by its nature a recognition of the individual and of individual differences This is a great advantage it avoids sterile classification and when properly administered encourages the worker to think of himself as a distinct human being

The objective of a good placement program is to fit the individual abilities of the person to the individual requirements of a specific job Thus two basic *elements* and two basic *principles* are involved One element is a knowledge of the specific demands of the job the second is a knowledge of the physical abilities of the employee Job analysis and preplacement placement or periodic examinations supply the necessary information First, with regard to principles all of these elements should be described by use of the same terminology (i e , uniformity in describing the amount of effort required by the job and possessed by the worker), and second the units of measurement should be sufficiently objective to prevent misunderstanding between those concerned in job placement—mainly the physician and personnel officer and the employee Figure 4 presents the basic requirements in the selective placement of workers (McFarland 1953)

The advantage of a method which uses objective units of measurement to describe the degree and duration and kind of effort for both job requirements and employee capabilities is that these elements can be rapidly and accurately compared Operational efficiency and safety are thus facilitated With regard to the latter, it is obvious that the worker should not be so placed that he may be a hazard to himself (e g the blind man should not be placed on an unguarded punch press or the epileptic should not be assigned to work requiring the use of ladders) Nor should he be a hazard to others in his place of work, a worker with a history of fainting spells should not be employed as an acetylene torch welder Finally, the disability of a worker if he has an overt disability should not be aggravated by the conditions of his job such as would occur if the employee with contact dermatitis were placed on a job requiring exposure to irritants Such accentuation of limitations is also very likely to occur in older workers over a long period of time even when placed on selected assignments More data of the long term effects of various types of work on the processes of aging are needed

OTHER METHODS

The oldest method of matching men and jobs is also the simplest the *intuitive*

method of selection, as, for instance, when the foreman hired likely looking laborers at the dock gate each morning While the de fects of this are clear, many exhaustively planned methods have not proved success ful Indeed, this field is strewn with the wrecks of plans for matching man and job, and the defects inherent in the concepts on that a man can be successfully placed on one of the jobs listed as being suitable for his specific disability This understandable error resulted in a work which fills several printed volumes (U S Civil Service Com mission 1952–55) The essential point missed here is that, with similar disabili ties, surviving abilites are also judged

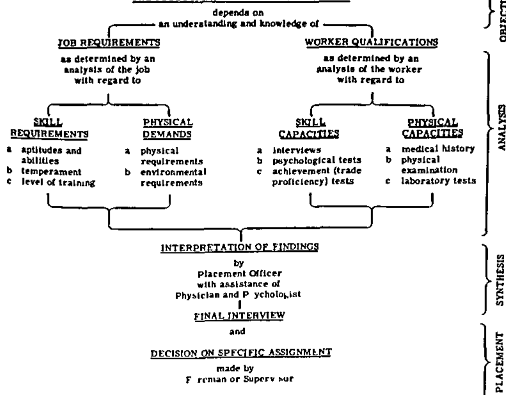


FIG 4 —Plan for the selective placement of workers by matching job requirements and worker qualifica tions (From McFarland 1953)

which these methods were based have with time, been more or less accentuated Of these perhaps the disability method and the rating method are the most important This latter is still the most widely used of the formalized placement methods today

The *disability method* is based on the theory that jobs can be listed which are suitable for persons with specific disabili ties (e g , one armed or one legged persons or even ' elderly" people) This implies equal Every person in any disability group has his own pattern of remaining abilities which makes him very much of an individ ual This approach also limits by stressing disabilities rather than by pointing up the remaining abilities which may be used in a much greater variety of jobs In many areas where the disability method is used special lists of jobs are also set up for "elderly" workers, thus preserving the stereotype of linking old age with infirmity

The *rating method* estimates surviving abilities on a rating basis and matches them with the results of job analysis For instance both jobs and workers may be rated according to a scale such as arduous—moderate—light—very light or A—B—C—D and matching is then achieved by placing a B worker for instance, on a B, C or D job This is the essential principal, in the actual application of this method there are many modifications and the treatment is usually far more complex than in this example This approach satisfies completely our natural inclination to classify and rate according to some descriptive scale However the application of this method has led to considerable confusion in that the ratings while they appear objective allow only a subjective opinion to be expressed Attempts to redefine and limit these descriptive terms have not clarified the situation The basic misunderstanding lies in the fact that the interpretation of the physician's note of for example, 'no heavy lifting' by the placement officer is unpredictable and can be acted upon only according to his own concept of what this rating entails Quite often there is sufficient disparity in opinions as to cause difficulties —exclusion of workers from suitable jobs which they could perform or, conversely, the placement of workers in jobs beyond the range of their abilities This method thus does not comply with the second principle mentioned above The language used to describe both physical capabilities and job demands is not sufficiently precise

THE SPECIFIC METHOD

The specific method (or Hanman Plan after its author) emphasizes ability rather than disability As recently described (McFarland and Philbrook 1958) it deals directly with the positive abilities of individual workers and the specific demands of individual jobs rather than with the group concepts and averages used in the disability method It uses specific and objective units to measure the human effort required by jobs and possessed by workers for a series of standard human physical activities In the application of this method, the physical and environmental demands of jobs are recorded in units of time for eighty specific factors, as shown in the Profile of Physical Demands in Figure 5 Similarly, the physical abilities of workers are evaluated and recorded by the physician with the hour as the unit, as shown in the Profile of Physical Abilities in Figure 6 In Figure 7 the capacities of the drill press operator (Ned Raymond) is matched against the requirements of his job The precision of the descriptive terms (regarding kind, degree, and amount of effort) is such that there is little opportunity for misunderstanding between those engaged in placement The illustration demonstrates that in this instance, the physical abilities of the subject more than fit the demands of the specific job shown, at the same time allowing the subject a safe margin for off duty activities If necessary, these activities may be evaluated in the same manner Experience in a number of industrial situations has shown that it is not difficult for physicians to learn to evaluate ability in these objective terms In addition to its use as an employment technique the Profile of Physical Abilities (Fig 6) can in geriatric and rehabilitation cases, be filled out by the physician to define a patient s total permissible effort during his waking hours (Hanman, 1958) It then becomes a prescription for the individual geriatric or convalescent patient to guide him through his daily activities (McFarland and Philbrook, 1958)

A very basic step for achieving a successful integration of the job and the worker is to obtain specific information concerning the physical demands of the work The duties of the various jobs should be precisely stated on forms which cover the nature of each task, the percentage of time spent on each activity in detail, the difficulties and importance of the duties, and the precision with which an employee must operate Other facts should also include a description of the surroundings and haz

Profile of Physical Demands

Write in Numbers Maximum Hours Required Per Shift — *Blank Square: Not Required* — *E: Either Right or Left Permitted*

JOB TITLE ____________________

JOB LOCATION ____________________

PHYSICAL FACTORS

	No.	Factor	
	1	1—5 lbs	Total Lifting Demands Including Pushing and Pulling Effort
	2	6—10 lbs	
	3	11—25 lbs	
	4	26—50 lbs	
	5	51—100 lbs	
	6	100+lbs	
	7	1—5 lbs	Carrying Demands (Carrying means the portion of Total Lifting which requires carrying)
	8	6—10 lbs	
	9	11—25 lbs	
	10	26—50 lbs	
	11	51—100 lbs	
	12	100+lbs	
	13	Right	Fingering Fine Dexterity
	14	Left	
	15	Right	Handling Including Coarse Fingering
	16	Left	
	17	Right	Below Shoulders — Reaching
	18	Left	
	19	Right	Above Shoulders — Reaching
	20	Left	
	21	Right	Hammering or Throwing
	22	Left	
	23	Sitting	
	24	Total Time on Feet	
	25	Standing or Moving About in Small Area	
	26	Walking	
	27	Running	
	28	Jumping	
	29	Stairs or Ramps	Climbing
	30	Ladders or Scaffolds	
	31	Right	While Sitting — Treading Operating Foot Pedals
	32	Left	
	33	Right	While Standing — Treading Operating Foot Pedals
	34	Left	
	35	Stooping Low Back Bending	
	36	Crouching Knee Bending	
	37	Kneeling	
	38	Crawling	
	39	Reclining Working Horizontally	
	40	Twisting Spine	
	41	Waiting Time Periods of Inactivity on Job	
20/	42	Far Snellen	Vision
20/	43	Near-Snellen	
	44	Color	
	45	Depth	
	46	Hearing	
	47	Speaking	
	48	____________	Other Physical Factors
	49	____________	

ENVIRONMENTAL FACTORS

	No.	Factor	
	50	Inside or Protected from Weather	
	51	Fair Weather	Outside Without Weather Protection
	52	Wet Weather	
	53	Hot °F______	Due to Conditions Other than Weather
	54	Cold °F______	
	55	Sudden Temperature Changes	
	56	Humid	
	57	Dry	
	58	Operating or Around Moving Vehicles or Objects	
	59	Hazardous Machinery	
	60	Sharp Tools or Materials	
	61	Cluttered Floors	
	62	Slippery Floors	
	63	High Places	
	64	Electrical Hazards	
	65	Exposure to Burns	
	66	Explosives	
	67	Radiant Energy (Kind):____________	
	68	Poor Lighting	
	69	Poor Ventilation	
	70	Toxic Conditions (Kind):____________	
	71	Wet Working Quarters	
	72	Close or Cramped Quarters	
	73	Vibration	
	74	Noise	
	75	Working With Others	
	76	Working Around Others	
	77	Working Alone	
	78	Shifts	
	79	____________	Other Environmental Factors
	80	____________	

REMARKS ____________________

____

JOB ANALYST'S NAME ____________ VERIFIED WITH FOREMAN'S NAME ____________ DATE ____________

FIG 5.—Chart showing Profile of Physical Demands (From Hanman 1958)

Profile of Physical Abilities

Blank Squares = No Restriction

O No Ability

Written Numbers = Maximum Limits of Ability in Hours during { ✓ Waking Hours of 24 Hour Day / ☐ Working Hours of 8 Hour Day } Check One

NAME *Ned Raymond – Drill Press Operator* | *50* (AGE) | *70* (HEIGHT) | *162* (WEIGHT)

PHYSICAL FACTORS

Entry	No.	Factor	Group
	1	1—5 lbs	Total Lifting Ability—Including Pushing and Pulling Effort
	2	6—10 lbs	
/	3	11—25 lbs	
O	4	26—50 lbs	
O	5	51—100 lbs	
O	6	100+ lbs	
	7	1—5 lbs	Carrying Ability—Carrying Ability means that portion of Total Lifting Ability which may be used in Carrying
	8	6—10 lbs	
½	9	11—25 lbs	
O	10	26—50 lbs	
O	11	51—100 lbs	
O	12	100+ lbs	
	13	Right	Fingering—Fine Dexterity
	14	Left	
	15	Right	Handling—Including Coarse Fingering
	16	Left	
	17	Right	Below Shoulders — Reaching
	18	Left	
/	19	Right	Above Shoulders — Reaching
/	20	Left	
	21	Right	Hammering or Throwing
	22	Left	
	23	Sitting	
4	24	Total Time on Feet	
4	25	Standing or Moving About in Small Area	
2	26	Walking	
O	27	Running	
O	28	Jumping	
½	29	Stairs or Ramps	Climbing
O	30	Ladders or Scaffolds	
O	31	Right	While Sitting — Treading—Operating Foot Pedals
	32	Left	
2	33	Right	While Standing — Treading—Operating Foot Pedals
2	34	Left	
	35	Stooping—Low Back Bending	
O	36	Crouching—Knee Bending	
O	37	Kneeling	
O	38	Crawling	
	39	Reclining—Working Horizontally	
	40	Twisting—Spine	
	41	Waiting Time Periods of Inactivity on Job	
20/30	42	Far—Corrected Snellen	Vision
20/30	43	Near—Corrected Snellen	
	44	Color	
	45	Depth	
O	46	Hearing	
O	47	Speaking	
	48	______	Other Physical Factors
	49	______	

ENVIRONMENTAL FACTORS

Entry	No.	Factor	Group
	50	Inside or Protected from Weather	
	51	Fair Weather	Outside Without Weather Protection
O	52	Wet Weather	
O	53	Hot	Due to Conditions Other than Weather
O	54	Cold	
O	55	Sudden Temperature Changes	
O	56	Humid	
	57	Dry	
	58	Operating or Around Moving Vehicles or Objects	
	59	Hazardous Machinery	
	60	Sharp Tools or Materials	
	61	Cluttered Floors	
O	62	Slippery Floors	
	63	High Places	
O	64	Electrical Hazards	
	65	Exposure to Burns	
	66	Explosives	
	67	Radiant Energy (Kind) ______	
	68	Poor Lighting	
O	69	Poor Ventilation	
O	70	Toxic Conditions (Kind) *Lung Risks*	
O	71	Wet Working Quarters	
	72	Close or Cramped Quarters	
O	73	Vibration	
O	74	Noise	
	75	Working With Others	
	76	Working Around Others	
	77	Working Alone	
O	78	Rotating Shifts—Zero if only day shift is suitable	
	79	______	Other Environmental Factors
	80	______	

REMARKS *Diagnosis appears on physician's copy only. This man's diagnosis is: ① Deaf mute. ② Right leg amputated below knee—fair prosthesis. ③ Rheumatic heart disease. ④ Arrested tuberculosis ⑤ Nervousness when exposed to noise or vibration*

DATE *May 17, 1957* PHYSICIAN *S. S. Scott, M.D.*

FIG 6—Chart showing Profile of Physical Abilities. (From Hanman, 1958)

ards inherent in the work It is particularly important to have a clear statement of minimum requirements (McFarland, 1953) Recent literature on job analysis, description, and evaluation has been reviewed by Kendall (1956)

The specific method has innumerable modifications A less exhaustive method listing forty seven physical and environmental factors is suggested for use by Quimby (1956) The method has also been modified by Swedish workers (Forssman, 1955), using about half the physical factors and with the addition of some mental

Sketch of Adjustment Made Around the Clock for Drill Press Operator on Reverse Side

(1) Worker's abilities in hours for 24 hour day—(Blank Squares = No Restriction)
(2) Requirements of his new 8 hour job in hours—(Blank Squares = No Requirement)
(3) Worker's remaining abilities for activities off his job

(1)	(2)	(3)	No.	Item	
	3		1	1— 5 lbs	
	3		2	6—10 lbs	
1	½	½	3	11—25 bs	
0		0	4	26—50 bs	
0		0	5	51—100 bs	
0		0	6	100+ bs	
			7	1— 5 lb	Ca y ng Ab y
			8	6—10 bs	Car y ng Ab l y means he por on of To al L f ng Ab l y wh h may be used n Ca ng
½		½	9	1—25 lbs	
0		0	10	26—50 lbs	
0		0	11	51— 00 bs	
0		0	2	00+ bs	
	1		13	R gh	F nge ng F ne Dexte y
	1		4	Lef	
	7		5	R gh	Hand ng Includ ng Coa e F nge ng
	7		16	Le	
	2		17	R gh	Be ow Shoulde s — Reach ng
	2		8	e	
1		1	9	R gh	Abo e Shoulde s — Reach ng
1		1	20	Le	
			2	R ght	Hamme ng o Th ow ng
			22	Le t	
	6		23	S ng	
4	2	2	24	To al T me on Fee	
4	2	2	25	S and g o Mo ng About n Sma l A ea	
2		2	26	Wa k ng	
0		0	27	Runn ng	
0		0	28	Jump ng	
½		½	29	S a s o Ramps	Cl mb g
0		0	30	Ladde s o Sca o ds	
0		0	31	R gh	Wh e S ng — T ead ng Ope a ng Foot Pedals
			32	Le t	
2		2	33	R ght	Wh e S and ng — T ead ng Ope a ng Foot Pedals
2		2	34	Le t	
	½		35	S oop ng Low Back Bend ng	
0		0	36	C o h ng Knee Bend ng	
0		0	37	Kneel ng	
0		0	38	C awl ng	
			39	Rec n ng Wo k g Ho zon a y	
	1		40	Tw s ng Sp e	
			41	Wa ng T me Pe ods of Ina v y on Job	

(1)	(2)	(3)	No.	Item	
					V s on
0		0	46	Hea ng	
0		0	47	Speak ng	
			48		Other Physical Factors
			49		Other Physical Factors

ENVIRONMENTAL FACTORS

(1)	(2)	(3)	No.	Item	
	8		50	Ins de o P o ected l om Wea he	
					e o P o ect on
0		0	56	Hum d	O he than Weathe
			57	D y	O he than Weathe
			58	Ope a g o A ound Mov ng Veh cles o Ob ects	
	8		59	Haza dous Mach ne y	
	8		60	Sharp Tools o Ma e a s	
			61	Clu e ed F oo s	
0		0	62	Sl ppe y F oo s	
			63	H gh P aces	
0		0	64	E ec al Haza ds	
			65	Exposu e to Bu ns	
			66	Explos ves	
			67	Rad ant Ene gy (K nd)	
			68	Poo L gh ng	
0		0	69	Poor Vent a on	
0		0	70	Tox c Cond ons (K nd) *Lung Risks*	
0		0	71	Wet Wo k ng Quarters	
			72	Close o C amped Qua e s	
0		0	73	V b a on	
0		0	74	No se	
			75	Wo k ng W th O he s	
	8		76	Wo k ng Around Others	
			77	Wo k ng A one	
0	*Day*	0	78	Ro a ng Sh f s *Zero f only day shift s su table*	
			79		Other Environmental Factors
			80		Other Environmental Factors

FIG 7—Chart showing matching of (1) the physical abilities of a subject with (2) the demands of a job operating a drill press The worker's remaining abilities (3) for activities off the job are also listed. (From Hanman, 1958)

factors The results have been good, and this modification has been suggested as being more practical

Although the chart is perhaps the major device used for placement it is however, no *substitute for the opinions formed at inter*views examinations and tests Such information complements and qualifies the chart to some extent this system like any other is only as good as those who administer it Placement also involves follow up proce*dures to insure that the man and his job* are properly tailored and to discover and rectify any loose ends which become apparent only after employment has begun The federal law in relation to rehabilitation (Public Law 565) now demands that state plans shall make specific provision for ' a reasonable period of follow up after placement to assure that the vocational rehabilitation of the client has been successfully achieved (U S Department of Health Education, and Welfare 1954)

The specific method has been criticized on the point that it does not contain any consideration of the worker s emotional and mental needs and problems This ties in with another criticism that this method is geared predominantly for application to light and heavy industry Its application to such personnel as typists secretaries and salesmen may be less effective since job analyses in these occupations are far from complete The less a job becomes the exercise of mere physical skill the more demands it makes in areas of emotional maturity and adjustment For older workers these demands are made at a time when emotional adjustments in other directions are real problems (Thompson 1955) As Forssman (1955) has said, "There is great need for research into the different mental demands of certain work, and for recording the corresponding qualifications, as for instance as to ascertain the type of person who will fit in a monotonous job and the type who will be suitable for high grade responsibility and a post demanding cooperation with other people" Although numerous attempts have been made to measure emotional maturity (Havighurst, 1956, Henry, 1956, Peck, 1956), there is as yet no 'emotional quotient" comparable to the intelligence quotient of mental ability Successful adaptation to the problems of later *life is however, undoubtedly determined* by earlier emotional influences There is great need for controlled studies in this field, especially in relation to work in a wide variety of employments

THE VALUE OF TESTS

Tests of selection naturally depend on the job to be filled Their importance in placement is difficult to decide upon in an over all way, since their effectiveness in selection varies from employment to employment Kendall (1956) reports conflicting data as to whether the use of tests in industry is on the increase or not Generally, it would appear however, that about 50 per cent of companies use tests in engaging salaried employees With regard to selection of executives, this figure in one study (Habbe 1955) fell to 13 per cent. This is entirely reasonable when one considers that here there is a process of natural selection which makes the use of tests to a large extent unnecessary It would seem reasonable to say that tests are of greatest advantage when the applicants' performance is unknown and when the proposed employment is mainly concerned with special aptitudes No test or preplacement procedure, however, can guarantee that a particular worker will be a success at a particular job Uncontrollable factors of motivation enter here, after efficient job placement, success or failure depends on the worker Perhaps this is one factor which has led to severe attacks on psychological testing in industry (Whyte, 1954, Stessin, 1955)

New test batteries have been developed (Flanagan, 1954), and the older ones are being reported on from the point of view of their validity (Levine and Wallen, 1954, McArthur 1954) That there is much confusion and little unanimity in this field is

attested to by the innumerable methods in use The literature dealing with aptitude tests for older workers is limited, but Odell (1956), reporting on "a cross sectional analysis by five year age groups of the 400 case general population sample on which the General Aptitude Test Battery was standardized," gives the following results "The test performance with respect to all of the abilities measured by this method tends to show some decline with age, and the rate and amount of decline differ for the various aptitudes In general, test results for G (General Intelligence), V (Verbal Facility), N (Numerical Ability), and S (Space Perception) seem to be the least affected by age These test results for Q (Clerical Ability) and P (Form Perception) show a moderately greater decline with age by age groups And the test results for A (Aiming), T (Tapping), F (Finger Dexterity) and M (Manual Dexterity) show the sharpest and deepest decline"

The validity of the tests against job performance has not yet been established Odell also calls attention to the fact that older workers are at a disadvantage when tested against standards which have been evolved from groups other than the aged For instance, reporting on one study, he mentions that "test norms based on the total sample although showing good selectivity for the sample as a whole, tend to eliminate too high a proportion of the older workers in the high criterion group and not enough of the younger workers in the low criterion groups" He advocates the establishment of separate norms for older workers within each occupational group

Odell and Mapou (1953) have outlined test research design which would remove the bias against older workers by enabling them to be selected against just criteria From the point of view of job adjustment on a wider basis than aptitudes, Odell cites a recent study (Studdiford, 1953, Boling, 1954) which "indicates that there are many possibilities for increasing the utilization and mobility of older workers and handicapped workers by psychologically physiologically slanted job analysis and description methods" Changing the demands of the job has been suggested by Welford (1953) and by others as being the most important single practical measure in improving employment opportunities for older people The two major factors here are the speed at which the job must be performed and its actual complexity Welford makes a number of practical suggestions as to how these may be modified to suit the changing abilities of older people

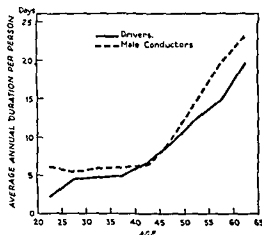
With proper placement and job adjustment for both older and handicapped workers, their productivity, absenteeism, and accident rates are comparable to those of other workers (Bridges, 1946, U S Federal Security Agency, 1946, Lloyd, 1947) The following quotation from a publication on medical examinations in industry by the Council on Industrial Health summarizes the findings in this area

> Proper placement of workers with due regard for the variations in physical demands required by different jobs and for the safety and health limitations involved in disabilities, can result in improved job performance, less absenteeism, decreased likelihood of injury less hazard to the health and safety of others, lessened chance of aggravation of disorders, and, doubtless, a longer productive life span Examination for and assistance in job placement are, therefore, practical, individualized applications of the principles of preventive medicine [Council on Industrial Health 1956]

IV Performance of Older Workers in Industry

The future for a group of workers in industry depends naturally on performance More correctly, it might be said that it "depends on performance *as measured*" There is disagreement on the criteria selected to measure efficiency, and more disagreement on how well they do so The *Annual Review of Psychology* in both 1955 and 1956 gave much consideration to this

that, 'while factors that resulted in increased job or personal responsibility were correlated with lower rates for younger workers, for workers 45 and over age itself appeared to be a factor in keeping rates uniformly low ' This finding was for male



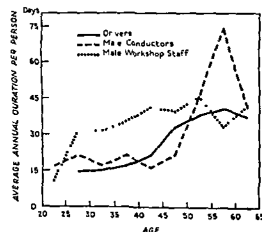


FIG 8 —Sickness absence in the London Transport by age Top curve shows absences of 4 days or more 1949–52 Bottom curve shows functional nervous disorders absences of 4 days or more, 1949–52 (From Norman 1958)

workers Women have a less favorable absence record

LABOR TURNOVER

The relation of age to frequency of labor turnover or to duration of employment is of practical importance In general, the older worker remains on a job longer than a younger one This fact has been shown by Kitson (1925) in an investigation of the records of four industrial concerns The results indicated a fairly steady and rapid increase in length of employment from 21 to 31 years of age, followed by a plateau and a further lengthening of service near the age of 50 In another study by Davidson and Anderson (1937), it was also concluded that the greatest occupational mobility took place under 35 years of age, few shifts to new occupations occurred thereafter

When all the above variables in regard to *industrial efficiency and safety* are balanced against each other in any given industrial situation, the value of each worker will vary with his productive abilities rather than with his chronological age In most occupations, however, accumulated experience adds more effectiveness than does speed or mere physical strength Industry is well aware of the desirability of prolonging the useful lives of its older workers In this way the social economy will be improved and the older person will be happier than if he is pensioned The increase in the proportion of older people among the population makes the attainment of this goal increasingly necessary

V AGING AS RELATED TO AIR TRANSPORTATION

The process of aging is of greater significance for airmen than for most occupational groups because of the exacting de

will depend on a knowledge of the amount of deterioration which can be normally expected at that time As a pilot grows older, the alterations in sensory functions may influence his efficiency significantly His vision may be altered so as to hamper his performance in landing Hearing losses

might interfere with his ability to interpret radio signals accurately Slowing reaction times for complex performance may reduce a pilot's ability to take the necessary actions required by modern, high speed jet aircraft These changes may vary greatly from one person to another in both nature and extent, but even minor deterioration in many of the psychological and physiological functions may interact to produce a significant loss in general efficiency (McFarland, 1953)

Although it is not yet possible to establish a retirement age for civil airline pilots based on scientifically determined facts, enough is known about the aging process to suggest that these pilots should retire at about the age of 60 The United States Federal Aviation Agency is proposing to rule that the retirement age shall be fixed at 60 and that no civil airline pilot shall be allowed to qualify to fly jet passenger aircraft after the age of 55 Although, on the one hand, the trend in aircraft instrumentation is toward reducing the amount of mental computing required of the pilot, he is at the same time becoming increasingly taxed by the demands of high performance aircraft and greater traffic density A high demand is at present being placed on the pilot in the operation of the various devices and systems designed to increase safety

An early retirement age for the average airline captain is of concern to management, since it means that the initial expense involved in training must be written off in a shorter time The military services have estimated that the cost involved in training a pilot is in the neighborhood of $100 000 Expense in training is not the only consideration it may be expected that the judgment and experience of the older pilots may also contribute to improved safety records and be of special value in the handling of large and expensive equipment Although the younger pilot may be as competent in the actual flying of a plane, repeated flights under many adverse circumstances give the older man a wider range of knowledge on which he can base a decision Not only may accidents be costly in terms of loss of life and equipment but they decrease confidence in air travel as a means of transportation and consequently lower passenger revenues (McFarland, 1953)

It should be kept in mind, on the other hand, that the present vitality and rapid growth of the aviation industry are intimately related to the youthfulness of the personnel and might be best maintained by an early retirement age One of the basic handicaps to progress in the American railroad system is the high percentage of older employees who cannot be easily retired In air transportation a similar situation may arise as the present group of employees becomes older Difficulties will occur not only in changing to new types of equipment but also in scheduling operations In many airlines choice of routes is governed by seniority thus in some cases the older pilots are able to choose routes which do not place excessive stresses on them In any one company the number of such routes is limited, however, and it may be difficult to maintain a reasonable flexibility in scheduling assignments Furthermore, the older pilot for reasons of pride or financial gain, may be tempted to choose a route which is no longer within his capabilities In this way the safety of the flying public may be jeopardized

The Age Distribution of Airline Pilots

Most discussions of the problem of aging in airmen contain frequent reference to the age characteristics of the pilot group At present it is possible to present only a cross sectional rather than a longitudinal study It is of interest, however, to study not only the present age distribution of pilots but also the numbers of older pilots expected to enter various age groupings in the future (McFarland, 1953)

The age distribution of all pilots, including student and private, commercial and air transport, is shown in Table 3 It may

be seen that although most pilots are aged 20–44 years more than 2500 were over 60 years of age as of January 1, 1955 About 85 per cent of this older age group are private pilots It is no longer possible to think of flying as being associated with younger persons only

TABLE 3*

AGE DISTRIBUTION OF ALL PILOTS ON JANUARY 1 1955

Age Group	No	Per Cent
16-19	10 183	2 91
20-24	39 538	11 31
25 29	73 664	21 06
30-34	89 502	25 59
35 39	60 007	17 16
40-44	35 700	10 21
45-49	21 972	6 28
50-54	11 326	3 24
55 59	5 173	1 48
60 and over	2 654	0 76
Total	349 729	100 00

* Source US Department of Commerce 1956

TABLE 4

AGE DISTRIBUTION OF PILOTS IN AIRLINE OPERATION 1946–54

Age Group	1946	1949	1952*	1954*
Under 24	269	46	6	12
25–29	2869	1791	363	375
30–34	2169	2703	3389	3 888
35–39	1232	1605	3191	4 274
40–44	464	942	1567	2 013
45–49	139	262	788	1 111
50–54	95†	139†	209	308
55 59			90	121
60 and over			16	27
Total	7237	7488	9619	12 129

Airline pilots comprised only a small proportion of the total group in the above analysis Age distributions for all pilots holding airline certificates have been obtained from the Civil Aeronautics Administration and are shown in Table 4 for the years 1946, 1949, 1952, and 1954 It is of interest to note the number of airline pilots who are entering the older age range for this industry (i e, 50–60 years of age) In the group over age 50, which is frequently designated as comprising the "older" pilots, there were 315 in 1952 and 556 in 1954 (U S Department of Commerce, 1954, 1956)

It is possible to predict the number of airline pilots who entered the older age range in 1957 and who will be in this age category in 1962 Table 5 shows these distributions based upon the 1952 data The significance and method of constructing this table are readily understood by noting that in a 5 year period, the number of each 5 year age group becomes the predicted number in the next higher 5 year age group Presumably, many pilots can be expected to retire at 65 and above However, if retirement does not reduce this group to smaller proportions, mortality can be expected to do so as shown in Table 6 On the basis of the age distribution of airline pilots in 1946 through 1952 it can be estimated that there were about 1100 airline pilots 50 years of age or older in 1957 and that this number will increase to over 2000 in 1962 On July 1, 1959, the Federal Avia

TABLE 5

PREDICTED NUMBER OF CLASS I MEDICAL CERTIFICATE HOLDERS IN OLDER AGE GROUPS ASSUMING A CONSTANCY OF NUMBERS OF PILOTS IN EACH BIRTH CLASS

Age Group	1947*	1952	1957†	1962†
40–44	712	1567		
45–49	209	788	1567	
50–54	120	209	788	1567
55 59	16	90	209	788
60–64	0	16	90	209
Total	1057	2370	2654	
50–64 years‡	136	315	1087	2564

* Estimated from 1946 data
† Predicted from 1952 data (see text)
‡ Estimates for pilots 65 and older are not made because of lack of experiential basis for doing so

tion Agency estimated that there will be about 80 airline pilots over 60 years of age in 1962 and about 250 in that age group by 1967 No longer can flying air transport planes be associated with very young men, as the above data clearly indicate The percentages of pilots in the older age ranges however are relatively small in relation to the age distribution of the general population

Several explanations have been advanced for the relatively small number of airline pilots in the older age groups The most common is that air transportation is a young industry Pilots entering the airlines at 20–25 years of age in the late 1920s and early 1930s when organized air transportation began would naturally not be over 55 at the present time The pilots who are 55 60 years old today were 25–30 when the first domestic airmail was carried by a commercial operator and the first passenger was flown in scheduled United States airline service in 1926 To be flying at age 55 60 today a pilot must have been born before Orville Wright first flew at Kitty Hawk in 1903 and be twice as old as the oldest existing United States airline It is clear that many pilots are now approaching the critical period between 55 and 60 years of age It is of great importance to both pilots and the aviation industry to analyze more extensively the effects of aging on the individual

Influence of Aging on Pilot Performance

Few better illustrations can be found of the importance of preserving the knowledge and experience of older employees than the case of pilots in civil aviation After an airline pilot has flown for many thousands of hours he possesses training and judgment in the air which cannot be purchased at any price Air transport pilots are a highly selected group and if they live wisely with regard to diet, exercise and the use of alcohol and tobacco many will be able to fly until fairly advanced years The question now arises as to what extent the slight but definite functional decreases in ability will influence the efficiency and safety of the older pilot A definite answer depends on studies of productivity labor turnover, accidents and sickness rates Such studies are not very extensive but some evidence is available (McFarland 1953)

PRODUCTIVITY

There is no way to measure productivity of air crews in the usual industrial sense except possibly in relation to the percentage of schedules fulfilled Experience has indicated that on the whole the older pilots are able to fly as frequently and as long as the younger ones and that age per se has not been a limiting factor On the average the airman who has flown until he is 40 or 45 years of age knows thoroughly the limitations and capabilities of both his plane and himself In their ability to set an optimum pace and maintain it, the older pilots are no different from highly trained employees in other specialized industries

TABLE 6

EXPECTED NUMBERS OF PILOTS IN DIFFERENT AGE GROUPS IN 1952 1957 AND 1962 BASED UPON 1952 DATA AND NORMAL MORTALITY RATES FOR WHITE MALES

Age Group	1952	1957	1962
40–44	1567		
45–49	788	1396	
50–54	209	632	1077
55–59	90	146	442
60–64	16	52	85
65–69	0	7	24
70 and over	0		2

LABOR TURNOVER

Changes similar to those described in the mobility of the labor force with age are to be observed in statistics relating to the cause of separation of airline pilots from service In Table 7 it may be seen that, of

262 pilots resigning, 126, or approximately 48 per cent resigned voluntarily The majority were under 35 years of age This readiness to change jobs may be explained in part by the fewer responsibilities of the young men by a more or less sudden realization on the part of some that they are not suited for or do not like flying, by disillusionment with the frequently overpublicized glamour of flying, and by diverse other reasons Each resignation and the necessity for training and adjusting a new man to the operational group, however may mean interference with schedules, temporary overburdening of the remaining airmen and the need for expensive training and check out flights From this point of view the older workers are a distinct asset in terms of continuance on the job as compared with men in their twenties and early thirties This greater stability and hence usually stronger loyalty, is especially important where training periods are long and expensive

TABLE 7

CAUSE OF SEPARATION FROM AIRLINE SERVICE IN 25 UNITED STATES AIRLINES IN 1956

Cause of Separation	No	Per Cent	Per Cent of Pilots Employed
Voluntary resignation	126	48 1	1 08
Discharge for cause	66	25 2	0 57
Reduction in force	33	12 6	0 28
Death	18	6 9	0 16
Retirement	10	3 8	0 08
Medical disability	6	2 3	0 05
Other	3	1 2	0 03
Total	262	100 0	2 25

ACCIDENTS

A few studies of the relationship among accidents, age, and experience in aviation are available One pertinent investigation deals with the statistical analysis of age and experience in relation to accidents in the United States Air Force

The findings are based on an analysis of all accidents occurring during the last 6 months of 1953 It was found that the average age of all USAF pilots was 31, whereas the average age of pilots experiencing accidents was 28 Pilots aged 25 and under were 16 per cent of the pilot pool but had 40 per cent of all accidents Pilots aged 40 and over were 3 2 per cent of the pilot pool, did 1 7 per cent of the flying, and had 0 8 per cent of major accidents There was a general decrease in accident rate with advancing age, except in flying jet aircraft, when the rate rose as age increased (Zeller and Moseley, 1957) It was found that age and experience could be correlated For any experience level there was a consistent decrease in accident rate with age (Table 8) For any age level there was also a trend of decreasing accidents with experience, but this was not so consistent

A more recent study concerning acci

over 1000 hours' experience This reversal of the earlier trend to higher accident rates in jet fighter pilots is believed to be due very largely to improvements in design and in training methods (Zeller, 1959)

Although complete data on all fatal and non fatal accidents are not available from the beginning of civilian air transport operations in the United States, a survey has been made of the ages of captains involved in fatal accidents in scheduled air carrier operations from 1950 through 1954 The number of accidents occurring in relation to age of pilot is shown in Table 9 An analysis was also made of the number of accidents per thousand pilots with active airline transport ratings by age groups The data for the above relationships are shown in Table 10 The results of all the above studies are summarized below (U S Department of Commerce, 1956)

1 A study of age distribution of captains of air carrier planes involved in accidents during 1950–54 suggests that no

TABLE 8*

AIR FORCE ACCIDENT RATES FOR ALL AIRCRAFT BY AGE AND EXPERIENCE† OF PILOT FROM JULY 1, 1953, TO DECEMBER 31, 1953

Age of Pilot	0–499 Rate	500–999 Rate	1000–1999 Rate	2000–2999 Rate	3000 and Rate	Total Rate
24 and under	76	28	35			70
25–29	58	32	26	26	28	37
30–34	16	22	19	18	10	17
35–39	8	19	25	15	16	19
40 and over	0	0	24	15	7	10
Total	61	27	22	18	12	29

* Source Zeller and Moseley (1957)

† Experience = first pilot hours plus instructor pilot hours

TABLE 9

AGE DISTRIBUTION OF CAPTAINS INVOLVED IN AIR CARRIER ACCIDENTS

AGE GROUP	ALL ACCIDENTS						FATAL ACCIDENTS					
	1950*	1951	1952	1953	1954	Total	1950	1951	1952	1953	1954	Total
25–29	6	7	5	3	3	24	3	1	2	2	0	8
30–34	20	29	24	21	19	113	2	8	5	7	4	26
35–39	23	27	21	26	19	116	5	8	2	4	2	21
40–44	11	17	15	11	14	68	1	2	1	3	1	8
45–49	7	3	5	7	13	35	1	2	3	4	0	10
50–54	1	2	1	1	1	6	0	0	0	0	1	1
55–59	0	2	1	1	1	5	0	0	0	0	0	0
Total	68	87	72	70	70	367	12	21	13	20	8	74

* Alaskan and helicopter operation and commercial pilots excluded

TABLE 10

NUMBER OF ACCIDENTS AND NUMBER OF FATAL ACCIDENTS PER THOUSAND PILOTS WITH ACTIVE AIRLINE TRANSPORT RATINGS, BY AGE GROUPS

AGE GROUP	ALL ACCIDENTS			FATAL ACCIDENTS		
	1952	1954	1952 and 1954 Combined	1952	1954	1952 and 1954 Combined
Under 29	13 6	7 8	10 6	5 4	0*	2 6
30–34	7 1	4 9	5 9	1 5	1 0	1 2
35–39	6 6	4 4	5 4	0 6	0 5	0 5
40–44	9 6	7 0	8 1	0 6	0 5	0 6
45 and over	6 3	9 6	8 2	2 7	0 6	1 5
All age groups	7 5	5 8	6 5	1 4	0 7	1 0

* *Only 3 accidents occurred in this age group in 1954, none of which was fatal*

great variation in accident rate with age exists in this group of pilots None of these trends has significance statistically

2 When the number of air-carrier accidents per thousand pilots are calculated for 5 year age groups accident rates tend to increase slightly with increasing age of the groups This result is unreliable, however, because the analysis includes many pilots who were not qualified to act as captains of air-carrier airplanes during the period considered and who have a different age distribution from the group of pilots under consideration

3 A similar analysis based upon the age distribution of active airline pilots gives a pattern having proportionately the greatest number of both fatal and non fatal accidents in the youngest age group and the least number in one of the intermediate age groups This analysis is considered to be more reliable than the first but bias is known to exist (e g not all active Airline Transport Rating pilots are air carrier captains)

4 The most prominent feature of the pattern of results is that the ratio of fatal accidents to all accidents is highest in the youngest age group and lowest in one of the intermediate groups

5 In general, the fact that there is no definite increase in the number of accidents with age suggests that factors other than age may be important determinants of the accident rate On the average, the older pilots tend to have good records

AGING IN RELATION TO SICKNESS RATES

In a consideration of sickness rates among pilots, certain differences from the general industrial population must be kept in mind Flight crews are drawn from a more youthful population and have relatively few men in the older age groups The standards of fitness which the older workers must maintain are much higher, however, than in the general population The sickness rates for pilots are low, but there is an increase in *severity* of sickness with age, that is, the older pilots tend to remain off duty longer than younger ones once they are taken ill The rise in severity rates for the older group is especially marked when prolonged illnesses are included This finding is similar in other industries (McFarland, 1953)

THE EFFECTIVE UTILIZATION OF THE OLDER PILOT

Undoubtedly, the most important advantage which the older pilot has is the experience he has gained in flying various types of equipment under all conditions Although judgment cannot be evaluated in quantitative terms, in general the natural process of selection favors the survival of the competent pilot. The individual who has not learned by experience to exercise a high order of judgment sooner or later gets into difficulties and is eliminated from the active flying group

The major airline operators have set up medical departments to prolong the useful lives of pilots in order to take advantage of their abilities Many of these have contributed greatly to the training program and are living examples of the fact that pilots can retain their efficiency and aptitude for long periods of time The older pilots tend to serve as a stabilizing influence on the flight group and represent a valuable asset for morale and company loyalty

Many of the prejudices against older pilots do not stand up under careful examination It is often assumed that the man nearing 40 deteriorates in muscular strength and endurance, slows down in his reflexes, and begins to fail in his hearing and eyesight But it should be remembered that changes with age do not necessarily mean a decline in capabilities Compensation, as already mentioned, takes place for most deviations, and, if certain capacities diminish, others are enhanced For example, if speed of reaction is lowered with age, there occurs a compensatory increase in skill, judgment, and endurance In specific physiological tests involving pulse rate, the

older pilots manifest a relatively smaller increase in rate than the younger ones to the stress of adapting to exercise or to a diminution of oxygen in the inspired air The older subjects appear to have more stabilized cardiovascular systems Other physiological differences exist, but one can not arbitrarily say that they indicate better or poorer condition In general, it may be concluded that the older pilots can be utilized very effectively until they reach 60 years of age This observation would not have been acceptable or predictable in the earlier history of the air transport industry Most airline operators would have predicted earlier retirement ages for their senior pilots

VI Age in Relation to Problems of Highway Transportation

The general changes in the age composition of our population mentioned at the beginning of this chapter, are reflected also in highway passenger transportation and the trucking industry As the proportion of young persons is reduced, the trucking industry will be faced with sharper competition from other occupations for the proportionately smaller number of young men available in the labor market This competition can be met most successfully by higher wages and better working conditions The labor market will be freer, of course, in the older part of the population —the age range above 45 years The trucking and transportation industries like all others, will find it increasingly necessary in the years ahead to find ways of using more of these older men, by selecting them more carefully on the basis of relevant abilities, by placing them in positions or assigning them to tasks where any age related deficiency will not be a hazard and by making greater use of their accumulated experience and judgment. It thus becomes highly important to bring together and interpret the significance of data concerning the age characteristics of professional drivers and the relation of these characteristics to performance (Dennis, 1953, McFarland and Moseley, 1954, Le Gros Clark, 1957, Welford, 1958)

Relation of Age to Truck Driving Experience

Studies of the work history of truck drivers show that there is a strong tendency for them to stay in the occupation It will be pointed out later, however, that driving a truck is a young man's job (McFarland and Moseley, 1954) On the other hand the occupation has developed so recently that most of the men now in it have spent the greater part of their working lives at it Table 11 illustrates this fact and shows the regular increase in average years of experience with age The table is to be read, for example, that, in the age group 31–35 years, half the men had had 11 or fewer years of experience and half had had 11 or more years The men in this sample were all within the first month of service on new jobs in several trucking firms

TABLE 11*

Average Years of Experience of Several Age Groups of Newly Employed Truck Drivers

Age Group	Average No of Years of Experience	Standard Deviation
21 25	5	1 8
26–30	9	3 0
31–35	11	4 3
36–40	15	4 9
41–45	20	7 0
46–50	26	7 4

* Source McFarland and Moseley (1954)

The table shows that the men in this group had spent nearly three-fourths of their lives since they were 17 as truck-drivers In addition to the general trend for increasing experience with age, there is considerable scatter or variation within each age group in the amount of experience,

and this variation is widest in the older groups as would be expected

AGE DISTRIBUTION OF SELECTED SAMPLES OF TRUCK DRIVERS

The rapid growth of the highway transport industry is one of the major factors determining the age of the men who drive the vehicles The number of registered trucks in the United States has doubled on the average of once every 5 years in the last 40 years There are over five million professional truck drivers in the United States About one out of eleven of the nation s wage earners are in the truck transportation industry which is now second only to agriculture in the number of persons employed (McFarland and Moseley 1954)

The 1950 United States Census provides some data on the age distribution of professional motor vehicle operators The most relevant tabulation combines the truck drivers with farm tractor and other tractor operators with deliverymen and with routemen This distribution is presented in Table 12 which also includes certain other age distributions for comparative purposes

The census data are not in such form as to permit descr ptions of the age characteristics of drivers in the trucking industry as a whole Fifteen per cent of the truck driver group in Table 12 are deliverymen and routemen and the proportion of tractor operators cannot be determined The whole tabulation is based moreover on the census respondent s statement of occupation and there is no way of telling how many were actually in the trucking industry and how many drove trucks in connection with some other business Further difficulties involved in interpreting these census statistics are illustrated by the fact that whereas the census tabulates about *1 32* million truck and tractor operators the Bureau of Publ c Roads reports that 6 1 million non farm privately owned trucks were registered in the United States in 1950 a year in which there were also 3 2 million farm tractors The indicated ratio of less than 0 2 driver per non farm truck is much lower than the estimate of the trucking industry which places the figure at 0 8 Also the census gives a total of 630 000 in the trucking service industry while the trucking industry itself reports a total 5 230 000 employees These discrepancies and the problems of definition and classification which they raise make it desirable to collect further data on defined samples of truck drivers if their characteristics as related to age are to be analyzed

A beginning has been made in this regard and age data have been collected on a number of samples of truck drivers which give a useful notion of their age composition and of some of the factors influencing it (McFarland and Moseley 1954) Figure 9 *1* and the next to-the last column of Table 12 show the ages of the drivers of a long haul trucking firm which carries small parcels This company is engaged in interurban and interstate transport picking up and delivering small consignments The median age of the drivers is 36 with the middle half of the group covering the 10 year range from 31 to 40 years although the total range for the group is 42 years—from 21 to 63

In Figure 9*B* and in the last column of Table 12 are shown the ages of the drivers of another long haul company which carries straight loads This work usually involves transportation of single consignments carried from a terminal or shipper to another terminal or a receiver where the loading and unloading are most often done by the dock crew or with mechanical aids The median age of the group is 40 with the middle 50 per cent in the eleven year range from 35 to 46 The whole range however is about the same as that of the first group 43 years—from 23 to 66 The second group is as a whole about 4 years older than the other a difference which is probably explained in large part by the nature of the physical work required of the straight load driver as compared with

that of the "small parcel" driver The latter will usually lift and carry 10,000–20,000 pounds in a day s run, and there has doubt less been some significant selection, either on the part of the drivers themselves or by their employers, whereby younger men with greater strength are more likely to be in the employ of the company represented in Figure 9*A*

that the men of a single company are less variable in age than a larger heterogeneous group is not unexpected, but it emphasizes the fact that age problems may have cer tain specific aspects which will be peculiar to a single company

Of interest for comparison with the fore going groups are the Roadeo contestants presented in Figure 9*C* This highly select

TABLE 12

PERCENTAGE AGE DISTRIBUTIONS OF EMPLOYED MALE MOTOR TRANSPORT WORKERS

Age	All Employed Males*	Truck and Tractor drivers Delivery men and Routemen*	Bus-drivers*	Taxi-drivers and Chauffeurs*	Trucking Company A†	Trucking Company B†
14–19	4 9	5 4	0 9	1 3	0 0	0 0
20–24	9 7	14 7	5 6	10 1	4 8	0 5
25 29	12 2	16 9	14 9	14 4	16 5	9 9
30–34	12 2	16 3	17 2	13 7	23 5	12 2
35–44	23 5	26 7	29 7	27 7	40 2	45 4
45–54	18 6	13 3	20 9	21 6	12 2	27 4
55–59	7 5	4 5	5 7	5 9	1 9	2 8
60–64	5 8	1 1	3 4	3 4	0 9	1 3
65 and over	5 6	1 1	1 7	1 9	0 0	0 5
Total	100 0	100 0	100 0	100 0	100 0	100 0
Median age	39 7	34 0	38 5	38 8	36 0	40 7
Interquartile range‡	22 4	17 0	17 3	18 9	10 5	11 0
No of cases	40 510 176	1 555 412	150 058	198 681	348	394

* Source 1950 U S Census

† Source McFarland and Moseley (1954)

‡ This is the range in years with the median at about its center which includes the middle 50 per cent of the cases For example in the first distribution half of the employed men in the United States were in the 22 4-year range from 28 5 years to 50 9 years

Table 12 gives some basis for comparing three census groups of employed motor transport workers with one another and with the employed males of the nation The motor transport workers tend to be younger than the total employed group, especially those reported as truck drivers, they are not so widely distributed over the age scale as the total employed group, as is indicated by the interquartile ranges The distributions of drivers of single companies have median ages higher than the census group of truck drivers and cover a considerably narrower range The finding

group of skilful drivers covers a narrower range of ages than the other groups, being especially lacking in men over 45 years of age They are selected on a competitive basis from all parts of the United States

AGE RELATED TO TURNOVER AND TO LEARNING JOB SKILLS

The data in Figure 10*A* and 10*B* were secured from 54 companies during a period of several years and have been combined to show the ages of all their employees at the time of employment and separation

(McFarland and Moseley, 1954) The net increase in employees in these companies, amounting to 1970 men, may mask some of the similarities between the two sets of figures The distributions are nearly the same shape and have the same average—30 years Both have peaks in the late twenties and taper off gradually in the thirties and forties A little over 2 per cent of the cases represented in each of the curves is in the age range of 50 years and over

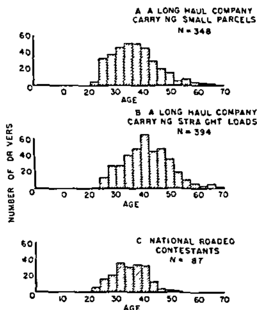


FIG 9—Ages of three groups of truck drivers (From McFarland *et al* 1954)

The difference between these two curves indicates the net additions in the truck driving force of these 54 companies This difference is plotted in Figure 10*C*, which can be analyzed to show that 70 per cent of the net increase is rather evenly distributed over the 15 year range from 21 to 35 Nevertheless, 12½ per cent (one out of eight) of the net new drivers are 41 or over, and 1½ per cent are over 50 years of age Considered in this way, the labor turnover of the trucking industry differs significantly from that of the railroads, where new employment is almost always in the younger years and where unreplaced separation characterizes the older ages

Figure 11 presents data to show the age at which a sample of truck drivers learned to drive a car, a truck, and a semitrailer Half of these men could drive a car before they were 17, and only 1 in 14 learned after he was 21 The distribution covers a wide range however, from 10 to 38 years These drivers usually mastered the truck a few years after learning to drive a car The median age is 20, the last 7 per cent learned after they were 27, and the distribution is again wide, from 12 to 40

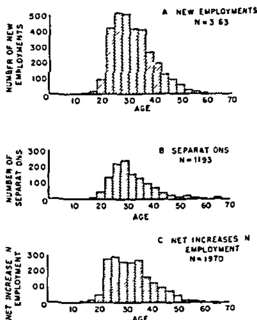


FIG 10—Ages of truck drivers at the time of new employment and at the time of separation from employment. (From McFarland *et al* 1954)

years About five sixths of these drivers have learned to drive a tractor semitrailer combination The median age of learning is 24 and the last 7 per cent learned when they were 35 or older The range of ages in this distribution, from 14 to 55, is about as wide as the age ranges in total driver groups shown in Figure 9

There are several implications of the data in Figure 11 First, mastery of driving

skill is almost without exception in the order car truck trailer The only exceptions in this group were three men whose prior experience had been entirely in driving farm trucks and one man who learned to drive a truck before he learned to drive a car Second these skills can apparently be mastered to an acceptable level of per formance in a few years Twenty six of the 311 trailer drivers presumably held a

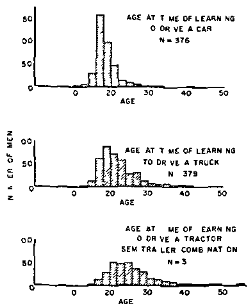


FIG 11 —Age at wh ch truck drivers learned to drive Reported age at wh ch 379 truck and tractor semitrailer operators learned to drive a car a truck and a tractor sem trailer (From McFarland *et al* 1954)

job at the age of 18 or less and 25 per cent of them before they were 21 the legal ICC minimum age Third although most truck drivers learn to drive while they are young there seems to be no upper age range in regard to mastery of the necessary skills The oldest 10 men to learn to drive a semitrailer d d so in the age range from 38 to 55 This range is the same as that which includes the oldest one third to one half of the working truck drivers according to the data of Figure 9 It is also the range wh ch includes about 20 per cent of the net new employees both truck and trailer drivers represented in Figure 10C

AGE IN RELATION TO ACCIDENTS

Insurance statistics and industrial rec ords have shown the popular bias against older employees as greater accident hazards to be a misconception In many instances when proper statistical control is made of the degree and extent of exposure the con trary has been found to be the case (New bold 1926 Kossoris 1940 1948 National Safety Council 1954)

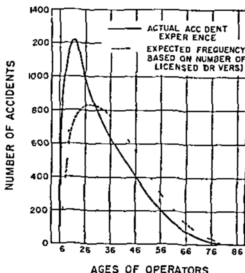
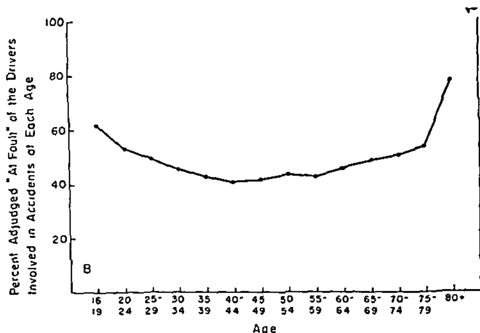
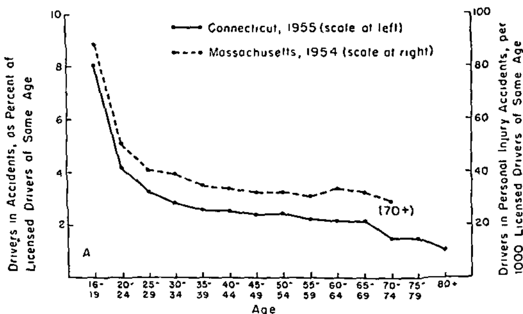


FIG 12 —Age and the frequency of automobile accidents. The graph indicates that drivers under 30 years of age have a much higher accident rate than would be expected from the number of l censed drivers in that age group (From DeSilva 1938)

In ordinary pleasure vehicle driving the age group under 30 has been found to pro duce the most accidents Figure 12 presents the results of a study of this problem in the state of Connecticut a number of years ago (DeSilva 1938) Similar results have been obtained in several more recent stud ies (Fig 13) (Lauer 1952 National Safe ty Council 1954)

Data are at present limited on the re lation between age and frequency of ve





in accidents, they are more likely to have made errors causing the accident (The points on the curves in and *B* are the averages of the values for the individual years in each age group)

hicular accidents among truck-drivers One study on 100 drivers of a southern trucking firm showed no correlation between age and frequency of accidents when amount of exposure (driving hours under comparable traffic conditions) was con trolled In another study in which 57 accident free drivers were being compared with 88 accident repeaters, a number of other differences were found, but none in relation to age (McFarland and Moseley, 1954)

A study of the relationship between age and accidents has been made for the 742 truck drivers represented in the combined *A* and *B* distributions of Figure 9 The statistical method and assumptions in this study are reported in detail elsewhere (McFarland and Moseley, 1954) It was found that *the safest age group was 45 years old and older*, followed closely by the age range 35–45 All this part of the age scale had a lower accident rate than expected The age range under 35 and

TABLE 13

AGE AND LENGTH OF EMPLOYMENT OF DRIVERS OF PROPERTY CARRYING VEHICLES INVOLVED IN COLLISION ACCIDENTS IN INTERSTATE COMMERCE 1949

AGE GROUP (YEARS)	EXPERIENCE						TOTAL
	Less than 1 Year	1 3 Years	3 6 Years	6 10 Years	10 Years and Over	Not Reported	
Under 19	6	1					7
19	5	4				1	11
20	8	9	1	1		3	22
21 24	1256	676	99	15	1	61	2 108
25 29	1941	1226	416	118	18	87	3,806
30–34	1374	995	498	216	114	81	3,278
35 39	918	785	446	270	198	66	2,683
40–44	495	413	297	163	226	33	1 627
45–49	211	194	156	113	137	15	826
50–54	74	82	85	38	106	15	400
55 59	18	21	20	13	45	7	124
60–64	4	4	7	6	17	7	45
Over 64	4	2	1	6	10	1	26
Not reported	15	7	1	2	1	39	65
Grand total	6330	4419	2027	963	873	416	15 028

* Source *Motor Carrier Accidents 1949* (Washington, D C Interstate Commerce Commission 1951)

The Interstate Commerce Commission has analyzed some of its data on accidents to show the relationship between collision accidents involving trucks and the age and the experience of the truck drivers concerned These data are presented in Table 13 These figures do not reveal the relation of either age or experience to the causation of accidents, however, because neither the age nor the experience distributions are known of the total population from which these accident involved drivers came Also no data are available on the exposure of this population

especially the group up to age 24 had far in excess of their expected accidents No evidence was found to support the notion that old truck drivers are less safe on the highway than young ones when all the conditions of operation are equal

AGING AND PHYSIOLOGICAL AND PSYCHOLOGICAL COMPETENCE

Truck driving is frequently considered a young man's job Although there is some justification for this belief, the apparent youth of truck drivers stems, in part, from

the rapid growth of the industry Other factors which should be considered are discussed below

Physiologically, there is evidence to show that muscular strength decreases with age In any truck driving job that requires much lifting and carrying therefore, an older man is at a disadvantage as compared with himself when he was 25–30 The wide variations in strength and skill among individuals at any age may allow the older man some relative compensations, but they cannot be expected to make up entirely for the general fact of decreasing strength with increasing age It has been observed that the older a man is the more likely he is to leave truck driving as a profession either voluntarily or involuntarily

Some of the sensory changes mentioned previously in regard to hearing and vision can be critical in this occupation The progressive loss of visual efficiency at low levels of illumination probably increases the hazard involved in driving at night, since it may mean delay in becoming aware of objects at the limit of the headlight beam Hearing losses may reduce the efficiency of the truck or bus driver in personal relations and lessen his ability to perceive abnormal noises from his equipment However a similar situation as that described previously for airplane pilots may characterize the hearing performance of truck drivers in a cab

Personal observation of many drivers on the road suggests that the belief of some of the older ones that they are slower and less able to meet a crisis than they once were reflects a disability of practical importance This may be true even when their actual loss in ability is minor The anxiety which may accompany such an awareness can make a man less capable of good judgment in all sorts of situations Adjustments to this kind of difficulty can be of various kinds Some older drivers have been observed to compensate for their more limited reduction in motor capacities by driving at lower speeds It has also been noted that many show less concern about being behind schedule than do younger drivers

Age changes in learning and remembering and in using new materials and new abilities have been demonstrated and are reported in detail below These changes are, however not so important in connection with the use of material which has long been known or in situations where there is plenty of time to understand and respond to a new situation (Welford, 1958) Although Welford (1953) has reported on a valuable experiment in the retraining of motormen as bus drivers, we have little data on truck or bus drivers directly Results on other types of workers, however, would lead one to expect that older drivers would have greater difficulty in adapting to new equipment or new ways of operating it and to modifications of routes and of procedures This would be especially true in complex situations involving road conditions, traffic, the load and the power plant When a degree of judgment is required and a series of operations must be carried out rapidly, the older driver may be poorer

Simplifying the operation of a bus or truck would ease the pressure on an older man in such situations, in the way that power steering and power brakes relieve him of the necessity to put out as much muscular force as he used to do Nevertheless, the situation the commercial driver meets is more like that of the airplane pilot than it is of the railroad engineer in the number and variety of stimuli which he must take in and in the speed, skill, and judgment which he must show in responding to them Indeed the job of driving is more demanding in its continuity than that of the pilot The driver must pay continuous attention to his surroundings, in front, to the side, and behind the pilot, once in the air can relax for considerable periods of time, being required to concentrate fully only during landings and take offs We would expect

uli and responses involved in driving trucks and busses

HEALTH PROBLEMS IN OLDER DRIVERS

With regard to other aspects of employment among older transportation workers, a recent study by Le Gros Clark (1957) follows the industrial and medical records of 300 London busmen from the age of 60 onward It was pointed out that this occupation, owing to medical supervision and the demanding nature of the work, tended to be more highly selective than many other industries in the retention or discharge of older workers Table 14 shows the number of drivers and conductors re-

TABLE 14*

RATE OF INDUSTRIAL SURVIVAL AFFECTED BY AGE ILL-HEALTH AND DEATH

Age	Per Cent Still on Job	
	150 Drivers	150 Conductors
60	100	100
63	86	85
65	78	80
66	50	35
67	31	26
68	21	23
69	15	16
70	7	11

* Source Le Gros Clark (1957

maining in employment at selected ages after discharges because of the effects of age, ill health or death Table 15 shows the percentage of retirements or transfers associated with certain specific illnesses for the 60–70 years of age period

It will be seen from the above tables that more than 80 per cent of the men left employment for reasons of age ill health, or death Several sought other jobs, how many were successful is uncertain The *table of complaints would seem to show* that drivers and conductors aged 60–70 may be equally subject to vertigo and hernia The slightly higher incidence of bronchitis, rheumatism, and gastric complaints among conductors is possibly explained by the greater stresses to which the conductor is exposed when dealing with the travelling public and to the more active nature of his job The slightly higher incidence of cardiac degeneration and thrombosis among drivers lends some support to the evidence that coronary thrombosis is more common among sedentary workers

TABLE 15*

PERCENTAGE OF RETIREMENTS OR TRANSFERS CONDITIONED BY CERTAIN COMPLAINTS AT AGES 60–70

Nature of Complaint	Percentage of Men Apparently Quitting Their Jobs for This Cause	
	150 Drivers	150 Conductors
Bronchitis (chronic or series of recent bouts)	18 0	22 0
Hernia	2 7	2 0
Gastric (peptic ulcers or recent bouts of gastritis)	6 0	10 0
Hypertension or vertigo	8 0	8 0
Cardiac degeneration, thrombosis etc	7 3	6 0
Rheumatic (fibrositis arthritis, etc)	10 0	12 0

* Source Le Gros Clark (1957)

In a recent study by Norman (1958) absences of 4 days or more caused by functional nervous disorders are charted for three types of London transport workers—drivers, male conductors and male work shop staff Each shows a different pattern, which may be directly related to the specific stresses associated with their jobs (Fig 8*B*) The sudden increase for conductors at around the age of 50 is remarkable

The difficulties exhibited by the men after 60 in the Le Gros Clark study is perhaps *relevant to the study reported by* Welford (1953), in which severe impairment of capacity to readjust and learn

was shown after 60, while satisfactory learning occurred in the great majority of subjects until around that age Le Gros Clark also reports that in the mid sixties *some of the men though otherwise in passa* bly good health began to find the job fatiguing and a source of strain It seems probable that *when the ratio between* diminishing capacities and compensatory reactions becomes even slightly negative, fatigue and the beginnings of complete dis organization quickly appear

The report stressed another important fact The relatively high proportion of workers who are obliged to make a transfer need some kind of alternative work The bus authorities attempt to provide this employment for those who must retire for health reasons before reaching their pen sionable age The number of light jobs is, however limited, and the demand much *greater than the supply* Thus *those who* are given these lighter jobs are compulsori ly retired at 65 to clear the field for those *younger who are now considered more eligi* ble For those compelled to retire after 65, there is no offer of alternative work Here the report stresses the unpleasant fact which is common to a great many indus tries that many men who have to retire beyond the mid sixties while capable of light work have no prospect of further em ployment The problem of providing alter native jobs is a difficult one which still requires a practical solution

It seems reasonable to assume that if truck drivers were in permanent pensiona ble employment with the incentive to re main at their jobs, similar findings would be obtained As has been shown, however, there is a tendency among them to move out of such employment with advancing age Le Gros Clark's investigation is a val uable index of what occurs when older people are pushed beyond their diminishing powers by job demands which remain con stant and do not allow a wide number of compensatory mechanisms to come into play

In summary, data concerning the dis- tribution of ages among drivers of trucks, tractors, and delivery vehicles have been gathered from several sources (1) the United States Census, (2) the Interstate Commerce Commission, (3) the American Trucking Association s Roadeo contestants, (4) 700 drivers employed in the industry *in New England*, and (5) *750 drivers in* selected samples While driving a truck is in a sense a young man's occupation, as the age of the population shifts, propor tionately more men over 45 will be driving There is a tendency for a positive correla tion to exist between age and experience in driving Newly employed drivers are typi cally 21–35 years old, and there is not a large proportion of drivers over 45 in the trucking industry Several factors may ac- count for this (*a*) the youth of the indus try (*b*) the amount of physical work which has to be done on the job, and (*c*) losses related to age, such as in auditory acuity visual acuity, sensitivity of the eyes at night speed of learning, and ability to *adapt to new equipment as vehicle designs* change While some of the last group of changes may imply that the older driver are deficient the chief *difficulties arise* when critical judgments and operations have to be made against a stringent crite rion of time, heavy lifting, and driving at night However, many older drivers com pensat [illegible]

ning, [illegible]

data give no support [illegible]

older drivers are more liable to accidents than younger drivers The management of trucking operations might be able to pro long the useful working careers of their older drivers by shifting them to daylight operations, free them from operations in volving heavy lifting, and place them on equipment with which they are familiar Some facts relevant to the health of older workers in transportation are presented from a recent report on 300 London trans port workers over 60 Attention is drawn to the scarcity of jobs for workers at or beyond their mid sixties who are still capa ble of light work

VII RETRAINING THE OLDER WORKER

Modification of the job to meet changing capacities has been suggested as an important method of keeping the older person employed and generally of widening his field of employment The other great possibility in extending employment is training or retraining older workers to extend their abilities to meet the requirements of selected jobs and a wider variety of job demands in general This naturally implies education, re education, and learning among older adults and emphasizes the field of learning during the older segments of the life span

It is unfortunate that this is one of the most sparsely documented areas in aging studies, and research in this field is comparatively new How novel it is may be realized by the fact that the section on association and learning in a standard text book (Stagner and Karwoski 1952) makes no mention of the effect of age on these processes beyond maturity Lawrence's recent review (1958) contains no reference directly pointed toward learning in the later years Shock s (1957) *Classified Bibliography of Gerontology and Geriatrics*, covering the six years from 1949 to 1955, lists only twenty one references on learning

LEARNING STUDIES

Adaption of job demands to the older worker capacities naturally depends on our knowledge of the physiology and psychology of aging Without this knowledge we are considerably handicapped The methods used in retraining the older worker also depend on our knowledge of his capacity to learn and of the way in which he learns Almost all learning studies to date have indicated a fall in ability to learn with age The early classical work of Thorndike (1928) indicated a peak age for learning in the early twenties, with subsequent decline very few of his subjects were however, over 40 Research in this area since then, including the various theories of learning, is described in chapter xix This research would seem to have brought out a number of points which have considerable practical implications with regard to employment and training of older people

An important point brought out by Welford as a result of the Cambridge studies is that learning capacity, especially in paced conditions, is seriously affected by the changes with age in the central perceptual ability to organize incoming data The tendency of this and other studies to accent the importance of perceptual processes in skilled performance in older people make this area one of the most important in which to concentrate future research

There is a great deal of evidence to show that one of the essential differences in learning performance between young and old is the amount that has to be retained or held in short term memory during learning In the older person short term memory would seem to be most impaired in tasks in which there is a continuous intermittant intake of information which demands serial response The attention given to the latter seems to affect adversely the storage of the former in short term memory This would appear to be another finding which demands modification of learning techniques

As to the cause of this deficiency, a number of theories have been advanced As noted previously, however, one experiment demonstrates a striking resemblance between certain of the psychological changes that occur with age and the effect on the same functions in younger subjects when they have been deprived of oxygen (McFarland, 1952) The question thus is raised whether in the older person, the difficulty in immediate memory may result from a deficiency in cerebral oxygen supply consequent to an impaired circulation and/or from altered brain metabolism in cortical functions

Older persons also seem to learn better in some situations than in others It may be that, handicapped by deficiencies in

short term memory, the aging mind remembers differently, within the limitations which allow only a certain amount to be handled at once Older people may have learned in certain situations to select and grasp the essentials most relevant to their needs interests and preservation and they are most likely to recall such data when confronted with the actual situation to which it can be applied That remembering in itself is a highly selective process lends some possibility to the theory that this process may be refined within the limits imposed by age It thus seems advisable to qualify studies of learning in older people with the question, 'Learning for what?"

Another common observation with older people is the variability within older age groups of the results of testing The degree of this finding is perhaps sufficient to cause doubt regarding generalizations made from such data Also this may lead one to question exactly what functions are measured by tests or indeed, not measured by them With age the uniqueness of the organism seems to be accentuated, aging increases total experience and, as both experience and the individual's reaction to it vary, so does the subject—the end result of a lifetime of habits and disciplines—display or fail to display unique aspects when submitted to psychological testing There is evidence too that there is less decrement in performance among more able subjects (Foulds and Raven, 1949) This wide variation makes standardization of tests for older people very difficult Welford (1957) has summarized the methodological difficulties in investigations arising out of such a dynamic concept of aging

ATTITUDES TO LEARNING

From what has been said it is apparent that current theory has tended to emphasize age changes in perception and in short term memory as important sources of difficulty in learning among older people Naturally these will be of considerable importance in drawing up training programs for the older worker There is a large body of work, however, which takes up these factors where others leave off This deals with the social background Pressey (1956) suggests that motivation to learn when advanced in years is proportional to the opportunities provided by and expectations existing in our society In the older years cultural and social expectations subside, and opportunities become more limited

Older people tend to show anxiety in learning situations especially if they are placed in a competitive position This is particularly so if younger people are included One employment service found during the initial interview that many older women being retrained as office workers were reluctant to attend classes with younger girls (U S Department of Labor, 1953) Camp (1942) has reported on the learning capacities of two professional men, aged 35 and 72, no difference was observed between them in tests in which the older was unconscious that his learning was being observed and compared with the younger When he was so informed, and both were then given a learning task, Camp concluded that the older man was handicapped by feelings of inferiority in the competitive learning situation which affected his performance The older person requires understanding and reeducation in his attitudes toward learning concurrently with younger people The increased self consciousness which maturity develops appears to have the effect of making older people more reluctant to make mistakes in learning than the young There appears to be a tendency to "freeze" and not give the opportunity of appearing to be inferior The young are comparatively undisturbed by errors which they apparently accept as a part of learning and occasional *failures* do not have the disintegrative effect that they quite often seem to have on the old The planning committee on education at the first National Conference on Aging (1951) reached no definite conclusion on whether or not the aged should be segre

gated in educational programs It is interesting that the major dissenting votes against non segregation "came from those *members of the groups who had already* reached an attitude in years which permitted them to speak with the voice of experience"

Calling for research in this still almost untouched area, Donahue (1956) says "From the educator's point of view the matter of attitude of the learner is of major importance Studies are needed which will make clear the extent to which difficulties of older people in learning are those resulting from changes in ability and to what extent they are the effects of experience and unfavorable attitudes" At the present we know little about changes in ability and less about the attitudes which qualify these changes We are badly in need of a methodology in the field of instruction for the older adult

One point which needs elucidation is the attitude of older persons to tests The fact that our testing may be biased by variables of which we have little understanding as yet has led to disquietude among workers in gerontology from time to time (Arnhoff, 1955) Many of the older persons' insecurities are definitely *stimulated in test* situations A great deal of light might be thrown on motivation and personality structure in older people by a full investigation of their attitudes to specific tests and to testing in general The valuable paper by Havighurst (1950) on problems of interviewing among older people has not received the attention it deserves

FIELD TRAINING STUDIES IN INDUSTRY

Data on the field training of older people in industry are not very reliable from the point of view of drawing conclusions and making generalities It is obvious that, in observing the older worker in this setting, it is difficult to control important variables Of these latter, one of the most disturbing is that for numerous reasons there seems to be a process of selection among older workers which would tend to include only those whose abilities are adequate for the job Most observations have been made in the light- and heavy industry fields, and *data on the retraining of non industrial* workers (e g, salesmen, insurance agents, etc) are scanty It is difficult also to define the effects of motivation on such performances Wide fluctuations in motivation may occur even in the same person on different tasks

One important study took advantage of the switch made from trams to busses in South London (Welford, 1953) Tram drivers were given the opportunity to train as bus drivers, not many refused this offer, and one can only presume that the variable of motivation controlled itself here to an extent which allows more validity in the results than usual The course ran for 3 weeks, or 4 if necessary, and many failing after this course were allowed to take the complete course again Data on about half of those who accepted the training course were accumulated, and the results for these subjects are shown in Table 16

A continuous fall in those passing after 3 weeks is shown after the mid thirties, with a slight improvement in the 51–55 group With time however, there was little decrease in the proportion of those who *eventually* passed until after 60 The fact of previous experience in driving was also checked in a sample of the group undergoing retraining Those who had such experience did better than those who had not but that such experience was not essential is shown by the numbers in the later age groups who passed without it (Table 17) Such experience remains, however, an important variable, and it would have been interesting if such a breakdown could have been accomplished on all those who took the original training Valuable information might also have been forthcoming if it had been possible to gather data on the methods of training and on the ages of the instructors with the individual results of each as related to age groups As a result of a study of rural craftsmen, King (1955) has queried as to whether it may be more ad-

vantageous to use older instructors to train older men This study remains, however, one of the most opportune and valuable in the retraining of a large group of subjects of different ages on the same task (Welford, 1953)

That adequate training, however, may not mean efficient, continued performance was pointed out by R. M. Belbin (1955) in an investigation of the difficulties older people experienced in 32 firms Most of the difficulties in training and performance were associated with what he called "time stress"—an accentuated tempo of work He concluded that "difficulty in training seemed to be due to inability to acquire a

TABLE 16*

RESULTS OF RETRAINING TRAM DRIVERS AS BUS-DRIVERS

	Age Group							
	26 30	31 35	36–40	41–45	46–50	51–55	56–60	61–67
No of persons	104	106	146	92	63	62	61	60
Per cent passing in 3 weeks	93	97	90	83	65	71	44	32
Per cent passing in 4 weeks	3	2	9	12	23	8	25	10
Per cent passing in 7 weeks	1	1		2	5	11	24	21
Total per cent passing	100	100	99	97	93	90	93	63

* Source Welford (1953)

TABLE 17*

RESULTS OF TRAINING DRIVERS DIFFERING IN AGE

Experience with	Age Range			
	Twenties and Thirties	Forties	Fifties	Sixties
	Trainees Passing in 3–4 Weeks			
Trolley bus	2		13	10
Car or lorry	43	11	15	8
Both kinds	4	1	1	
None with other road vehicles	17	9	22	3
	Trainees Failing or Discontinuing			
Car or lorry (none with trolley bus)			1	3
None with other road vehicles	2	7	11	16

* Source Welford (1953)

NOTE —The numbers in this table differ from those in Table 15 because data regarding previous driving experience were collected from only some of the trainees

particular rhythm or knack while difficulty in continued performance showed itself not so much as a decline in the acquired skill but as a failure to withstand the strain of continuing work

With regard to performance and training it is interesting that a study by Eunice Belbin *et al* (1957) on young subjects found that there was no correlation between the performance of trainees when undergoing training for a specific task (later described) and their production rate afterward when engaged in industry The authors attributed this to factors within the firms in which the trainees subsequently worked (e g poor discipline lower standards of work etc) and not specifically related to their training These empirical findings on the difficulties of older workers are in accordance with those on the disorganization of skilled performance under conditions which involve speed obtained in laboratory studies as previously noted (Welford 1958)

Welford (1953) also reports on a series of field training data involving age comparisons For the most part these studies show declines with age in the time taken to train in the number of errors made in theory tests and in practical tests A number of trainees (women) on a cigarette inspection task however showed no decline in performance with age It was not possible however to draw conclusions with any confidence from these results Another study controlled a wide number of variables in relation to the learning progress of a large number of subjects in four general classes of shopwork (coil winding punch press operating etc) (Hayes 1932) The percentage of quick learners defined by an output over the average for the total new employee group diminished with age Most of the subjects here were however under 30 Bowers as reported by Speakman (1956) obtained appraisals by foremen of certain traits for 3162 workers with a wide age range engaged in a broad variety of tasks and found that few older than younger workers were reported to learn quickly

The data in all these experiments may have suffered from the lack of control imposed by field conditions The difficulty of many of these results lies in the fact that the training *method* does not seem to be under control. Learning in older people may be a reflection not so much of their true capacities as of the method employed Older people may not do well in training by methods which have been standardized for the young just as they do not perform well on tests which have been standardized for the young There may be a parallel here between the ineffective performance of older people in intelligence tests standardized on youthful subjects and their apparent improved performance on such a well standardized adult test as the new Wechsler Adult Intelligence Scale

RECENT STUDIES ON TRAINING

The importance of methods of training is stressed by the results of Belbin *et al* (1957) in training operators for the mending of worsted cloth In this occupation faults resulting from spinning and weaving have to be detected and removed and invisibly mended before final processing and dyeing A careful job analysis indicated that the essential difficulty in learning to mend was perceptual in nature A method was evolved by which the operators learned to perceive the necessary cues quickly and easily This was done by initially training with large scale weaves which magnified the difficulties and enabled correct relationships to be rapidly learned for a number of different weaves The size of the weave was then according to the trainees progress progressively reduced to the normal size This process eliminated the necessity to unlearn habits incorrectly formed Compared to two other traditional methods of training the results were clearly superior especially with regard to the time involved

An interesting point in the above study was the significantly lower scatter of results with regard to time among those trained by the new method (both for indi

viduals and for the group) This method developed perceptual skill by limiting the number of cues and eliminated those which were irrelevant to skilled performance and which might have caused confusion in learning This seems in line with the suggestion of Annett and Kay (1956), the skilled man they say, "responds to fewer cues than the unskilled If, therefore, irrelevant cues can be eliminated and the trainee is left with only those on which the skilled operator depends, there should be an economy in time and effort in the training period As it was stated earlier, much of the difficulty in learning in older people seems to be in perception This method, if it could be extended to other areas of training in older people, would appear to solve one of the major problems Bartlett's (1951) comments on the nature of skill also seem relevant here

Belbin (1958), following the lead given by herself and her co workers in training older people, has made a study of what she calls "activity" learning as against the "memorizing" methods which obtain in most industrial situations The "activity" *method substantially decreases the strain* placed on short term retention by conscious *memorization of instructions and also does* away with the necessity for the translation *of instructions from words to action, or vice* versa The "activity" method, in short, substitutes learning by "doing' for learning which depends primarily on memory of instructions

Using these two methods, Belbin conducted three experiments, two of them laboratory tasks, while the third consisted in teaching older subjects the skill of mending worsted cloth as already described The first experiment involved relating numbered cards to colored slots in a box in which the cards were, after correct learning, "posted" Marked differences were found between the two methods of training in two groups of subjects whose ages ranged from 20 to 70 The subjects trained on the activity method were proportionally faster and tended to be more accurate There were, however, a number of uncontrolled variables possibly influencing these results, and the next experiment, though basically similar, was designed to eliminate these sources of variation

The task was now modified so that subjects had to sort cards, numbered from 20 to 79, into six different slots in the lid of a box All the 20's were to go into one slot, all the 30's into another and so on, relating each family of ten cards to their specific slot As in the first experiment, there were two methods of learning the associations between slots and numbers One group learned by memorizing small numbered slips attached to the slots The numbers were removed, and the subjects' memory of their position was tested before doing the main task The second group learned from a pack of cards, each bearing the pattern of the slots printed on it. Each card had one number against its appropriate position among the slots Each card had to be posted into the slot indicated by its number These subjects thus discovered the number position relationship while performing the task Both groups were left to themselves until they were *satisfied* that they had learned the positions and were *then transferred to the main task* The time spent in learning was measured by a stopwatch, *as was the time required* to post each six cards of the main task The subjects were *divided into two* groups of eight, one between 18 and 22 and the older between 30 and 49

An arbitrary criterion performance of 10 seconds to sort six cards was set Table 18 shows the times required by both age groups to reach this figure, using different methods Although the older subjects were slower than the young with both methods of training, the difference was both absolutely and proportionately much greater with the memorizing method than with the activity method An important difference was noticed between the groups, *the criterion* was reached more quickly by the younger group after *memorizing than after* activity learning The older subjects

showed the opposite Apart from being slower in learning time, the older subjects using the activity method differed little from the younger group in performance time (i e time taken to ' sort)

The same pattern is also shown by presenting the results from a different view point The time taken to learn and the time taken to perform may be added together to show performances attained after constant time This is shown in Table 19 Again the younger subjects are better following memorization, the older, better after learning by the activity method As in the first experiment, accuracy for both groups was slightly better after learning by the activity method These results are highly relevant to studies which compare age groups learning by the same standard method It seems highly probable that biases in favor of one or other age group will affect comparative results by age (E Belbin 1958)

TABLE 18*

TIMES TAKEN TO REACH CRITERION PERFORMANCE OF 10 SECONDS PER SIX CARDS IN BELBIN S SECOND CARD SORTING EXPERIMENT

(Totals per Group of Eight Subjects in Minutes and Seconds)

	Memorization		Activity Learning	
	18 22 Yea s of Age	30 49 Years of Age	18 22 Years of Age	30-49 Years of Age
Cycle at which criterion was reached	12th	27th	7th	6th
Total time to reach criterion	24 14	60 39	32 17	43 3
Total made up of				
Learning time	5 34	11 15	22 10	33 47
Time performing main task	18 40	49 24	10 7	9 16

* Source E Belbin (1958)

TABLE 19*

MEAN INDIVIDUAL CYCLE TIMES BY AGE GROUPS REACHED AFTER 2027 SECONDS IN BELBIN S SECOND CARD SORTING EXPERIMENT

	Memorization		Activity Learning	
	18 22	30–49	18–22	30–49
Cycle time (in seconds)	9 5	13 4	10 3	11 0

* Source E Belb n (1958)

The essentials of the third task that of mending worsted cloth, have already been described It should be mentioned that the task is one which is regarded as too difficult for older workers Training is slow, requiring many months, and some trainees usually fall out Training is by apprenticeship, during which the trainee watches an experienced mender and then tries the work herself under supervision Progress is by a sort of trial and error process Twelve housewives between 30 and 50, none of whom had previous experience in invisible mending, were selected as subjects One group of six was trained by the traditional 'sit by me' method and the other by Belbin s new method, based on the presentation of selected perceptual cues, which facilitate the succeeding motor component to get under way correctly As stated before, presentation is controlled according to the trainees' progress One subject being trained by the traditional method resigned early

Table 20 shows that training by the new method yielded markedly better results, while Table 21 compares the times taken

by older and younger trainees to reach the same speed in mending 6 inches of weave The results are very significant Older subjects learned in a few hours speeds which the younger subjects took weeks to match Why there should be such a difference between the older and the younger group is not clear Again no claims concerning rates of production can be made from these results (E Belbin 1958)

By way of summary it is obvious that a great deal remains to be done before one can talk with any confidence about methods of training for older people What is certain, however, is that it is now recognized that older people, just as they perceive differently from those younger, also tend to learn best by methods which perhaps may not be suitable for the young but which are adjusted to their own changing patterns of ability Certain leads exist such as those already mentioned—in perception and memory—as to what psychological changes their educational programs should be adjusted It is obvious that no sound methodology of learning or training can be developed until the nature of other changes is clear An understanding of them is nec

TABLE 20*

MEDIAN TIMES (IN MINUTES) TAKEN BY SUBJECTS AGED 30–50 TO MEND 6 INCHES OF WEAVE AFTER 8 HOURS' TRAINING BY TWO TRAINING METHODS

Training Method	Type of Weave		
	1×1 Plain	2×2 Hopsack	2×2 Twill
Traditional sit by me method	6 6	5 9	Unable to do task†
Belbin s alternative method	4 5	3 1	5 5‡

* Source E Belbin (1958)
† Three subjects out of five were unable to do the task
‡ One subject out of six was unable to do the task

TABLE 21*

COMPARISON OF TRAINEE MENDERS AGED 30–50 WITH THOSE STARTING TRAINING ON LEAVING SCHOOL

	Type of Weave		
	1×1 Plain	2×2 Hopsack	2×2 Twill
Median times taken by 30–50 age group to mend 6 inches of weave after 8 hours of training by Belbin s method	4 5 min	3 1 min	5 5 min
Training required by school leavers to attain same speeds as older group	5 5 weeks	10 weeks	3–4 weeks
Time required by school leavers to attain same speeds when trained by Training within Industry method	7 weeks	Not at all	4 weeks

* Source E. Belbin (1958)

essary if educational programs are not to be more or less empirical It will be noticed that there is a tendency for research to move away from scoring final achievements in learning on set tasks between young and old to an analysis of what the learning process actually consists of in older people This accent on how older people learn rather than what or how well they learn is an encouraging sign It may be that we shall end up with a number of training methodologies each relevant to specific groups of older people and each of which may provide optimal conditions of learning for that group depending on education training intelligence and background Learning among older people may within such limits prove to be essentially an individual equation—matching subject method and task—not unlike the matching of men and jobs described earlier

There is also need of a program of research from the point of view of attitude to learning among older people and how it affects their retraining It is time that thought was turned toward widespread education on facts of learning among older people as they are now known with the accent on what they *can* do A new generation is entering the older segments of the life span which would be receptive to such re education and would aid considerably in breaking down prejudice Perhaps this could be introduced at the factory level and by government leaflets This social approach will complement the work being done by Welford and others on the internal aspects of skills

There is one indefinite aspect of learning which seems relatively easy to settle This is the question of whether learning is a skill or not It would not appear to be too difficult to design and carry out experiments with either animal or human subjects to decide this point There is evidence to show that practice in learning improves the ability to learn It is important to have information on this point in setting up methods of training

From the information available it is possible to emphasize a number of points which may provide a framework for methodologies of learning for older people (1) With regard to perception older people are helped considerably by presenting the material in a way which will allow them to understand the essentials of the task Belbin s selective presentation of cues is an example of this Clarity of written instruction would also appear in many cases to be superior to verbal instruction as the older person can go back to check his information (2) The pace of the instruction should be slowed down to enable full comprehension as learning progresses or the pace should be under the trainee s control (3) The effects of aging on short term retention indicate that for some old people memorizing instructions and translating them into action is not ideal Learning by activity methods would seem more profitable where such methods seem indicated and can be applied practical instruction has been thought more suited to older people than theoretical indoctrination although this point does not have unanimous experimental support

Demands are made on both perception and short term memory in understanding complex tasks The breakdown of such material into components which are clearly related to each other and to the over all task seems necessary This however demands careful job analysis and is very much easier said than done Spacing training sessions with pauses may be valuable in training older people This is another area where a definite answer is needed The importance of avoiding the early learning of errors has been stressed difficulties in unlearning may make a task considerably more difficult for the older subject It seems essential to relate instruction and task as directly as possible to each other with opportunities for ambiguity kept to a minimum The more practical the learning methods the more efficient they will probably be as there is evidence that older people learn more efficiently for use Also it is highly important to avoid discourage

ment which is perhaps one of the greatest single difficulties in training older persons The personality and perhaps age, of the instructor are of course important and affect learning no matter what method is used

It will be seen that these facts do not easily fall into a system which can be applied to training the older person The educational level intelligence learning habits, and previous training of the individual may suggest or determine the method that should be employed in retraining him An older person s seeming inability to learn may be due to our inability to find a method which will enable him to do so More *progress may be made in the future* by looking not for a method to train older people but for a method to train *this* old person Such an orientation may be the one which will enable psychologists eventually to evolve suitable methodologies

VIII Summary

The efficiency of older people at work is considered Age changes in physical and mental functions, as they affect performance, are summarized Methods of matching older people and their jobs are described The performance of older people in industry is discussed with special emphasis *on highway and air transportation* Finally, the difficulties of retraining older workers are considered and some recent research on learning is described

The effects of aging vary so much from individual to individual that functional rather than chronological age is a more effective criterion in judging abilities No method of measuring functional age has yet, however, been standardized Most sensory changes do not interfere with performance, but changes in visual and auditory functions, though of less significance than is frequently supposed, are most likely to cause deterioration in performance Changes in psychomotor skill suggest that older people should not be placed on work requiring continuous rapid action This loss of speed, however, tends to be compensated for by greater accuracy and attention to detail

Definite changes in mental ability occur with age, though most of the standard tests tend to accent the degenerative component of these changes Complex situations, and conditions which emphasize speed are more likely to reveal deficiencies in the older person's performance Qualitative changes in such higher mental functions as judgment, insight, and comprehension tend to compensate for these measurable decrements Performance depends on the ratio between such declines and compensations, so that final achievement may change relatively little or may even at times improve

Most people are handicapped in regard to some jobs The changing pattern of abilities with age makes it important that correct matching of these abilities with the demands of jobs should be achieved This will allow optimum function of the worker The specific method, which considers the individual rather than dealing in terms of group averages, is as yet the most satisfactory method of achieving proper placement This method does not consider the emotional demands of the job or the worker's emotional patterns Our inability to measure emotional components is the main handicap here It is important to evolve tests the criteria for which are based directly on *the performance and capacities* of older workers Youth standardized tests tend to show up the aged at a disadvantage Careful job analysis would appear to offer the possibility of opening a wider number of jobs for older persons

It is difficult to find dependable criteria by which the effects of age on performance can be measured in industry As far as can be ascertained, aging is found to have little influence on industrial efficiency as measured by productivity, absenteeism and sickness, accidents, and labor turnover

An analysis of the age distributions of pilots in civil aviation shows a surprising number to be in the older age groups A considerable number of pilots are over 50 years of age It would appear that they are

able to perform these functions without experiencing much difficulty Flight checks and other physical and mental tests tend to detect any changes in ability which would affect performance, thus accounting for the safety record of these older men There is no evidence that older pilots have higher accident rates than the younger men One of the main problems regarding these older airmen is to maintain their performance with the introduction of jet transportation It is imperative to know the significance of age changes in relation to the demands of jet equipment

Although there are comparatively few drivers over 45 in the trucking industry, this number is expected to increase substantially There is a tendency, however, for older drivers to move away from this occupation One study on bus drivers reports that the majority of these men are affected by numerous difficulties from the age of 60 onward, both in health and in the performance of their jobs Older drivers appear to be under relatively greater stress in situations requiring rapid judgments or movements during limited time intervals as well as in driving at night or lifting heavy cargo Here, however, compensatory mechanisms are also brought into play There is no evidence to show that older drivers are more liable than younger drivers to have accidents

Our present knowledge of psychological changes with age is insufficient to develop a good methodology of training the aging, working population Important implications for training, however, arise out of demonstrated changes in perception and short term memory in older people The importance of examining the learning *process* in older people rather than scoring final performance has been accented by recent studies There are indications that learning in older people may be more of an individual process, depending on education, experience, and learning habits, than was hitherto suspected Eventually, a number of methodologies may be evolved for groups of people, depending on these variables The methods should be flexible enough to allow adjustment to individual differences within each group

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XV

Sensory Functions

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I Role and Importance of Sensory Changes in Aging

The Individual Organism

The purpose of this chapter is to explore age changes in sensory functions and sensations and the relevant associated structural and functional changes Perceptual processes will be considered in chapter xvi Any sensory impairment may affect the individual organism s ability to interact with its external or internal environment If the impairment is not too severe, the organism may be able to compensate for the deficit by a variety of means, such as using a different sensory modality, either in addition to or in lieu of the impaired modality or by intensifying the stimulus or prolonging its time of action Experience may also be used to predict what the stimulus is probably like The ability to compensate is limited by the nature extent and multiplicity of impairments In order to organize the information about aging and sensory functions a limited number of distinctions and concepts have had to be presented in this introduction

To interact with its environment, the organism must be able to obtain information about it The organism s ability to obtain such information hinges on its sensory receptors, which function to transduce the kind of energy change to which they are particularly sensitive into centripetal signals in the form of patterns of nerve discharges Although the subsequent neurophysiological events are not well understood it is known that the signal pattern may be altered at neuclei en route to the higher centers From a psychological view point the effectiveness of a stimulus can be evaluated only in terms of a measurable behavioral response by the organism, although such a response need be neither immediate nor subjectively conscious to the organism It is difficult to measure independently the events designated as "sensation " "perception," or "response" by psychological methods, since such measurements require the occurrence of all these events "Sensation is commonly defined as the (reportable) conscious awareness of comparatively simple stimuli, such as absolute thresholds or difference thresholds, as contrasted with 'perception," where the interpretation of complex stimuli is required

For convenience the neural mechanisms may be divided into "sensory" and "perceptual" mechanisms (Response and other processes will not be considered here) The transition between sensory functions and perceptual functions may be regarded as occurring at the site of 'symbolic transformation ' This term is meant to imply a selective recoding of signals In recoding, the signal pattern is summarized by categorization into pre established categories Selection is exercised when the amount of information transmitted by the sensory mechanism is too large for the perceptual mechanism to process *in toto* Under these circumstances there may be scanning of the

input from the "relevant" sensory channels and a (partial) suppression of input from 'irrelevant" sensory channels, possibly by means of inhibitory feedback systems The term "sensory functions" can be applied to the operation of the sensory receptors and their associated nerves and nerve tracts, and the term 'perceptual functions" can be applied to the operation of higher or cerebral centers Sensory functions can then effect responses in and by the organism without first passing through the perceptual mechanism Sensation cannot occur without sensory function (except possibly in hallucinations), but sensory function can occur without sensation One may hypothesize that "sensation" in the psychological sense occurs when the input from the sensory mechanism into the perceptual mechanism does not overload the latter's capacity and require it to make selection from a plethora of relevant stimuli When such selection is required, "perception" in the psychological sense occurs

TABLE 1*

AGE AND PREVALENCE OF BLINDNESS IN NORTH CAROLINA

Present Age	No of Blind Persons	Rate per 1000 Population
Under 6	130	0 22
6-14	485	0 65
15-24	871	1 17
25-44	1 818	1 50
45-64	2 354	3 66
65 and over	4,492	19 53
Unknown	168	
Total	*10 318*	*2 47*

* Source Hurlin (1953)

The Effect on Society

In a society consisting of individuals over a wide age spectrum, the age-related changes in the over all functioning of these individuals may assume considerable political and economic importance Therefore, it is necessary to assess the frequency with which major age related changes occur In the area of sensory functions, only vision and hearing have been studied epidemiologically Data derived from such studies give an indication of the distribution of impairment in the population, usually in terms of "blindness" and "hard-of hearing" conditions

Blindness —Using the criterion of 20/200 vision or worse for "blindness," the prevalence of blindness in North Carolina by age is shown in Table 1 The figures for North Carolina are used here because they are based on an actual count of blind persons (Hurlin, 1953) It is evident that the prevalence of blindness increases substantially past age 45 and sharply past age 65 A similar pattern emerged in a California study (Belloc, 1956) which used the same criteria of blindness Among recipients of aid to the blind, 65 years of age or older, the age at onset of impaired vision was under 45 years for 11 5 per cent, between 45 and 65 years for 30 7 per cent, and over 65 years for 54 0 per cent The close agreement between these two studies should be noted, since one is based on prevalence, while the other is based on incidence of blindness

On the basis of eye examination reports, the California study (Belloc, 1956) found that the five leading primary pathologies of blindness were lens cataract, 34 9 per cent, glaucoma, 16 0 per cent, arteriosclerotic disease of choroid and retina, 11 3 per cent, retinal degeneration, 7 5 per cent, and optic nerve atrophy, 5 6 per cent

Deafness —Prevalence of impaired hearing shows a similar age related pattern Using the experience of the National Health Survey of 1935-36, Beasley (1940) showed that the prevalence of socially impaired hearing, equivalent to an average hearing loss of 47 decibels or more for 1024 and 2048 cycles per second by tone audiometry, showed marked increase past age 45 and continued to increase rapidly thereafter, as is shown in Table 2 It is noteworthy that a consistent sex difference does not manifest itself until past age 55, males then

showing an increasingly greater incidence and prevalence of hearing impairment than females

Vision and hearing are the two most important senses for the social human organism Malfunction of either probably can be compensated for in part by use of the other, but, when both decline simultaneously, as in aging, a serious social problem occurs Not only may the productivity of such persons be impaired, requiring the diversion of economic wealth toward their maintenance, but the social organization must take their limitations into account if the environment is to be so manipulated as to allow older citizens to achieve maximum utilization of their faculties

TABLE 2*

PREVALENCE AND ANNUAL INCIDENCE RATES FOR IMPAIRED HEARING (ANY STAGE) ACCORDING TO AGE AND SEX BASED ON NATIONAL HEALTH SURVEY EXPERIENCE OF 1935 AND 1936

AGE PERIOD	PREVALENCE (DEAFNESS CASES [ANY STAGE]† PER 1000 POPULATION)		INCIDENCE (AVERAGE ANNUAL RATE‡ OF NEW CASES PER 100 000 POPULATION)	
	Male	Female	Male	Female
Under 5	0 49	0 43		
5–14	2 95	2 26	33	24
15–24	3 51	2 93	6	7
25–34	4 76	4 99	13	21
35–44	9 70	9 28	49	43
45–54	14 93	15 45	52	62
55–64	29 27	26 43	143	110
65 74	73 64	54 68	444	283
75 and over	175 08	135 95	1014	813

* Source Beasley (1940)

† Equivalent to an average hearing loss of 47 db or more for 1024 and 2048 cps

‡ New cases per year at each single-year age throughout specified age period.

II VISION

The visual apparatus is amazingly adaptable, functioning over a wide range of light intensities and colors, distances and areas It has been estimated that the receptor elements of the retina in the area of their highest concentration are approximately one light wave length apart, which allows an extremely fine degree of visual resolution of detail Visual functions have been studied extensively, but few have been studied in relation to age The classification of visual functions is arbitrary and not entirely satisfactory, therefore, a certain amount of overlap among the following sections is to be expected

Accommodation

The eye focuses on objects at various distances by changing the focal length of the lens The normal eye at rest will focus objects which are virtually at an infinite distance The eye accommodates to focus near objects by increasing the refractive power of its lens, that is, it shortens the focal distance of the lens Maximum accommodation decreases with age from about 20 diopters at age 5 at the rate of about 0 3 diopter per year until it reaches a value of 0 50 diopter around the age of 60 years, after which there is generally no further decrease Hofstetter (1944) has compared the values for accommodation obtained by Donders and by Duane, as

shown in Figure 1 He states that Duane's monocular values are probably too low, the values he obtained for binocular accommodation agree much better with those of Donders Donders values outside the range of 20–65 years are probably less accurate because of his method

One caution about reported age changes in accommodation must be kept in mind

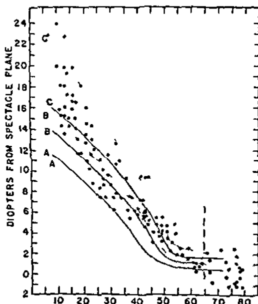


FIG 1 — A comparison of the trend of the amplitude of accommodation according to Donders (*dots*) and according to Duane (*curves*) All specifications are made with respect to an assumed spectacle plane 14 mm anterior to the cornea *A B* and *C* represent Duane's minimum mean and maximum monocular values respectively *A B* and *C* represent Duane's minimum mean and maximum binocular values respectively The scattering of Donders findings above the age of 65 is exaggerated by the computation method employed in transcribing the original data (After Hofstetter, 1944)

As Ferree and Rand (1933) have shown increasing the intensity of illumination decreases the near point of vision and thereby increases the apparent diopters of accommodation They found that the old showed a disproportionate improvement compared to the young, especially those presbyopes having greater refractive correction for near vision In order to control the effects of different pupillary apertures, they compared the results of natural pupils with those obtained with a 2 56 mm artificial pupil Only about one third of the improvement of apparent accommodation could be attributed to the greater focusing action of the smaller size pupils at higher intensities The remaining two-thirds they attributed to more central factors

Accommodative near point after glare exposure is changed differentially with age Peterson and Simonson (1951) found no change in young subjects, while the accommodative near point in a group of 47–80-year old subjects receded significantly after glare An increase of glare accentuated this age difference In a group of five aphakic older subjects glare produced no change in accommodative near point, indicating that the effect of glare on accommodative near point was probably in the lens

Three alternative theories of presbyopic change in accommodation are listed by Duane (1931) (1) Helmholtz's theory that the lens is passively elastic and that decrease in elasticity produces presbyopic accommodative changes, (2) Tscherning's theory that accommodation is due to forces acting positively on the lens and that these forces as well as the lens change with age, and (3) Duane's theory that both the lens and the muscular forces acting upon it change In support of his theory, Duane carried out experiments on the rate of effect of atropinization on accommodation which showed that the rate was about the same for all age groups Although these results are interesting per se, they do not necessarily lend exclusive support to any one of the three theories

Fincham (1955) studied the effects of homatropine and eserine on accommodation produced by convergence as a function of age He found that both the maximum accommodation and the rate of change of accommodation on convergence were reduced with age Homatropine reduced both the maximum and the rate of change at all ages Four subjects, aged 27 to 35 years were subjected to eserine instillation All

showed a rise in maximum accommodation but it is not clear from the given data if the rate of change was altered If the rates of change were not altered it might indicate that the convergence method used did not elicit the maximum possible accommodation A difference in rate of change might indicate a change in the accommodative mechanism Tait s study (1951) showed a decrease in accommodative convergence with age (see below) If Fincham s eserine experiment showed an increased rate of accommodation with convergence the use of eserine in Tait s experiment might reduce or eliminate the age differences he found in accommodative convergence

Accommodative Convergence and Phorias

In binocular vision the visual axes of both eyes must converge on the object When the object is at a virtually infinite distance these axes are parallel When the object is fairly close to the eyes not only do the eyes turn sharply medially but they also show accommodation Fusion of the image is the major factor regulating convergence but accommodation alone will also produce convergence

Mellick (1949) testing horizontal ductions by means of the synoptophore (a device for measuring strabismus) and the variable prism stereoscope found that the effects of age were slight Although there might have been an indication of greater range of both abduction and adduction for subjects in the second and third decades of life the results did not show a sufficiently consistent trend to permit drawing a conclusion of age change

Kephart and Oliver (1952) examined 8000 records of far and near lateral phoria obtained on an industrial sample by means of the Ortho-Rater They found that at far distance there was a tendency toward increasing esophoria with age while at near distance there was a tendency toward increasing exophoria with age Since each eye sees a different object in this test there can be no fusion convergence the amount of convergence is determined by accommodation Since diplopia is not clinically common and Mellick has shown that older subjects are capable of essentially as great convergence as young subjects the change in lateral phoria with age is probably due to changes in accommodative convergence This was shown even more clearly by Tait s (1951) study of 4793 subjects 10–70 years of age In the four age groups 10–19 years 20–39 years 40–59 years and 60–70 years the computed mean values of delta (prism diopters of convergence) were 14 79 13 21 9 70 and 8 71 respectively The cumulative distribution curves for the four groups were found to be parallel ogives

Pupil Size and Reactivity

The reduction in pupil size and reactivity with age is a common clinical observation Howell (1949) in a neurological examination of 200 healthy patients ranging in age from 65 to 91 years found reaction of both pupils to light in 54 per cent of his cases in one eye only in 9 per cent and no response to light in either eye in 37 per cent Pupillary response to accommodation was found in both eyes in 41 per cent one eye only in 3 per cent and in neither eye in 56 per cent He found no response to either light or accommodation in both eyes in 28 per cent and in one eye only in 8 per cent As can be seen in Table 3 the incidence of positive reaction to light and/or accommodation tended to decrease with age Conversely the number of non reactive or fixed pupils increased with age Also in the older age groups more pupils responded to light than to accommodation which may have been a reflection of reduced accommodation with age

Birren Casperson and Botwinick (1950) measured pupil size in 222 subjects ranging in age from 20 to 89 years under conditions of darkness and 1 0 millilambert of illumination The mean pupil diameters and the standard deviations by decades are

shown in Figure 2 The mean pupillary diameter under both light and dark conditions declined with age The correlation between pupil size and age was found to be curvilinear The correlation ratio between pupil size and age was 61 in light and 70 in darkness A significant correlation of 83 was found between pupil size in the light and dark with age held constant The ratio of the difference in pupil area in the dark and in the light to the size in the dark (i e, D —L²/D²) gives an indication of the relative control of the iris over the amount of light entering the eye Under the conditions of this study this ratio was about 0 53 and differed only 0 02 between the young and aged groups indicating that the older pupil constricted as much as the younger in relation to its initial size This constant efficiency of contraction with age has been confirmed by Kumnick (1956*a*) However, the velocity of constriction decreased with age In a separate paper Kumnick (1956*b*) indicated that pupil size extent of constriction and response velocity during decay of psychosensory restitution decreased with increasing age and that variability of response tended to increase with age (Psychosensory restitution is the response of the fatigued pupil to a sudden loud noise) Decay of psychosensory restitution was greater in dilation than in constriction for all ages but more so in the middle age range than in the youngest and oldest groups The relationship between age and decay of psychosensory restitution was found to be roughly linear, negative, and significant

In the same group of subjects, aged 7 5–90 8 years, Kumnick (1956*c*) found no significant difference between age groups in pupillary constriction latency in response to light in the rested stage, although the mean values were shorter for the younger groups However, Petersen (1956) found a bimodal distribution of constriction latencies one around 0 16 second and the other around 0 20 second The shorter latencies were contributed by his 0–18 year-old group Since Kumnick took photographs at the rate of 10 per second, while Petersen took 25 (and occasionally 50) pictures per second the discrepancy in results may have stemmed from methodological differences.

Since the amount of light reaching the retina critically affects visual functions, it is necessary to control or compensate for pupillary size differences The area of the pupil is not directly proportional to the amount of light reaching the retina because of the Stiles Crawford effect Crouch (1945) computed the increase in brightness required to maintain a constant effective image forming flux to compensate for decrease in pupil size His computations were based on the measurements of pupil size in

TABLE 3*

PERCENTAGE OF POSITIVE REACTIONS OF PUPILS TO LIGHT AND ACCOMMODATION

Age	No of Subjects	Light		Accommodation		Neither	
		One	Both	One	Both	One	Both
65–69	16	6	69	0	69	6	12
70 74	57	9	60	0	60	9	25
75–79	72	12	54	7	36	10	24
80–84	32	3	50	0	19	3	44
85–91	9	0	33	0	0	0	67
Mean		9	54	3	41	8	28

* Source Howell (1949)

daylight obtained by Nitsche and Gunther (1930) and are shown in Figure 3 However, Robertson and Yudkin (1944) found that the Stiles Crawford effect does not operate at threshold intensities or outside the fovea

As to the causes of senile miosis and rigidity of the pupil, Larsson and Österlind (1943) performed clinical and histological examinations on 14 irises of 69–85 year-old patients prior to and after cataract surgery with partial iridectomy Pupillary size prior to dilation with drugs ranged from 2 5 to 4 0 mm, after dilation with atropine, homatropine, and/or cocaine, the

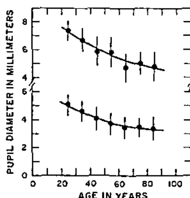


FIG 2 —Mean pupil diameter (mm) by decades Upper values derived from pupil size in the dark, *lower values from pupil size in 1 0 millilambert* brightness Vertical lines represent ± 1 standard deviation. Curves are regression lines derived from least square-fitting (After Birren Casperson, and Botwinick, 1950)

range was from 2 5 to 7 5 mm Some pupils were fixed, others dilated partly or fully The degree of arteriosclerotic changes found seemed proportional to the degree of immobility, as did the degree of hyaline degeneration of the iris and the atrophic and degenerative processes in the sphincter pupillae and the dilator pupillae They speculated that vascular changes preceded degeneration of the musculature and hyalinization of the iris stroma

Acuity

Visual acuity is usually measured in terms of the smallest visual angle at which detail can be discriminated This is expressed clinically as the ratio of the distance between the visual object and the subject, over the distance at which the presumably normal or emmetropic eye can discriminate the same detail For example, if the detail discriminated by a given subject at 20 feet can be discriminated by the emmetropic subject at 40 feet, the subject

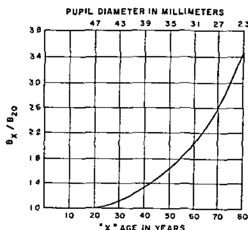


FIG 3 —Increase of brightness necessary to compensate for decrease in pupil size due to advancing age. B_x = brightness required at x years B_{20} = brightness required at 20 years (After Crouch, 1945)

is said to have 20/40 vision Visual acuity can be impaired by a large number of factors, such as clouding of the cornea, lens, or media, astigmatic changes in the cornea or lens, disparity between the focusing power of the lens and the lenticular-retinal distance, and changes in the structure or sensitivity of the retina itself

In static refraction of the eye the cylindrical and spherical corrections necessary to render the non accommodated eye emmetropic are obtained According to Slataper (1950), the average static refraction at birth is +2 32 diopters The hypermetropic change of early childhood to the age of

7 years is +1 617 D The axial myopic change of the young (8–30 years) is −3 327 D the hypermetropic change of middle age (31–64 years) is +1 362 D, and the senile myopic change (65–87 years) is −2 367 D He obtained these values from a large sample consisting of 14 868 ocular refractions by the single method and 20 702 refractions by the multiple or longitudinal method, with an average interval of 5 03 years between refractions He found that the multiple method was nearly fourteen times as accurate as the single method as determined by the

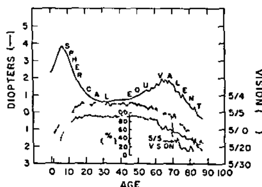


FIG 4—Age norms of refraction and vision

act and the dotted line branching from it shows patients with incipient cataract having vision of 5/40 or better The lower dotted line shows the percentage of patients having 5/5 vision or better (After Slataper 1950)

probable error and mean deviation He combined his data with those of Brown (1938), whose results were similar He reduced all refractions to their spherical equivalents This may be criticized on the grounds that spherical and cylindrical changes are not clinically directly relatable Walton (1950), using a longitudinal sample, showed that, while the average spherical refraction changed over the life-span, the average cylindrical correction remained zero with symmetrical distribution curves The changes in the spherical equivalent with age as obtained by Slataper are shown in the top curve of Figure 4 The sharp myopic change past age 70 is due to the development of cataract Swelling and sclerosis of the lens produce myopia, while flattening produces hyperopia When flattening does not occur, "second sight" may result These results may show an exaggerated average abnormality when taken for the population as a whole, since emmetropic persons are not so likely to seek an eye examination as those with visual difficulties This may also apply to young hyperopes, who can compensate for their defect

Hofstetter's (1954) study indicated that cross section studies of the mean spherical correction among clinical patients may not reflect the true trends in individual patients The rate of change of refractive error among adolescents seemed remarkably related to the presence of myopia itself, and the rate of change of refractive error among older adults was relatively constant throughout the later years and unrelated to the type of refractive error present Bucklers (1953) also showed that in myopics the curve of refraction has a steeper ascent over the first two decades of life At about 20 years of age the curves flattened Generally, the greatest increase in myopia occurred in those who had earlier and greater manifestations, but there were exceptions to this He also showed that the two eyes may change differentially (anisotropia)

Morgan (1958) studied a small longitudinal sample of men and women from age 13 to 33 years Hyperopes tended to become more hyperopic, and myopes more myopic Females were found to be relatively more myopic than males at age 13, and this tendency increased to age 33 The larger numerical change in myopia than in hyperopia gave a mean myopic change, which is the usual finding There was an increased astigmatism in the vertical meridian in females, similar change in lens curvature in males did not lead to increased astigmatism

Bernstein and Bernstein (1945), using data of repeated refractions on a large

number of subjects showed that it is possible to produce a good prediction of the course of presbyopic lens changes from three determinations over a 6 year period They state that all three elements of the prescription, namely the sphere for distance the astigmatic correction by a plus or a minus cylinder and the correction for near vision change with age Most of their subjects seemed to show the onset of such changes around the age of 42 They hypothesized that the total refraction develops according to a general aging process being the same for both eyes except possibly for the asymptote Their formula shows dioptric change with age as a logarithmic progression to the base 2

According to Slataper (1950) average visual acuity is 5/35 at 1 year of age 5/12 1 at 2 years and 5/5 at 12 years It reaches the maximum of 5/4 4 at the age of 18 and remains stationary until 62 when it drops to 5/5 2 At the age of 70 it drops suddenly because of senile changes in the eye These measurements were obtained with a metric chart at 5 meters on a 1 minute angle using standard illumination of 10 foot candles These results have been plotted in the second curve of Figure 4 The lowest curve shows the percentage of subjects having normal 5/5 acuity over the age span It must be noted that the average vision curve excludes subjects having cataract those with incipient cataract having vision of 5/40 or better are shown separately above age 70 After 80 the two curves tend to coincide because practically all eyes show nuclear changes with the slit lamp even though the lenses are apparently clear

Of particular interest are the data comparing vision in cataractous and aphakic eyes Average vision in both groups declined with age which indicates the decreased acuity in the cataractous eye may not be due solely to the cataract

Geldard and Crockett (1930) tested the visual acuity of each eye separately in 204 subjects ranging in age from 6 to 71 years, using Landolt rings (small rings with gaps in them) They found wider variation in acuity differences of the two eyes with increasing age when considered in relation

at all ages but the incidence of such cases decreased with age

The Effects of Structural Changes

In a study of 109 males subjects between the ages of 40 and 83 years Birren Bick and Yiengst (1950) found a high correlation between final rod threshold and degree of clinically observable retinal degeneration although even those subjects showing no observable retinal degeneration showed a rise in threshold with age It was not clear if macular degeneration produced a rise in threshold since the high thresholds obtained in subjects with macular degeneration were contributed by subjects showing retinal degeneration as well Subjects with advanced lenticular changes were excluded from the sample but the degree of lenticular sclerosis in the subjects tested did not correlate with final threshold None of the thirty nine subjects between 70 and 83 years was free of both retinal and macular degeneration and lenticular sclerosis the one subject free of retinal and macular degeneration had a final threshold at the level found in young persons The correlation between light threshold and visual acuity was 49 indicating that acuity alone is not an adequate measure of visual efficiency They also found no correlation between serum vitamin A level and light threshold and no significant improvement in light threshold after therapeutic vitamin A administration over as long as 76 days

The differential filtering action of older lenses for scotopic visibility has been described by Crawford (1949) using two subject groups averaging 18 6 and 57 2 years in age Adjusting the curves to intersect at about 0 5 micra wave length he showed that the curves virtually coincided

for the longer wave lengths, but the curves separated for the shorter wave lengths, showing a maximum difference of 0 2 log unit at 0 41 micra Similar findings on the relative loss of sensitivity to blue light were reported by Hess (1909*a*) who used an intensity matching procedure at scotopic visibility levels with a blue and a yellow red filter He found little age change up to 50 years but past that age there was considerable decrease in sensitivity to blue However he found good sensitivity to blue in the aphakik eyes of subjects over 50 In another paper Hess (1909*b*) reported the case of a 68 year old man with a ripe cataract in one eye and an incipient cat aract in the other who showed considerable relative decrease in blue sensitivity Cat aract extraction restored good sensitivity for blue Examining eyes in vivo and ex tracted lenses with blue light he found considerable fluorescence in older lenses They showed greatly diminished transmis sion of light from green through violet but they transmitted red light very well The extracted yellow lenses of two children who died of icterus showed no fluorescence to blue light and transmitted light very well The functional significance of the increased fluorescence is not known but it may be related to the findings on postglare effects reported by Peterson and Simonson which were mentioned earlier

Studying the relative transmission of red light Berner (1927) measured the absorp tion of ultrared by lenses of old horses and cows and compared her results with those of Schlapfer who had done this with young animals Using a wave length of 0 7 micra, she found the absorption to be 34 9 per cent in the old lenses compared to 22 3 per cent in the young How much of this loss was dispersion rather than absorption is not clear No comparable data are avail able for human lenses

As to structural changes in the lens apart from clinical cataract Kunert (1956) in a study of a hundred patients ranging from 30 to 80 years with approxi mately five subjects of each sex per decade, found an increase in fine precipitates and radial fissures past age 40, although about 30 per cent of the subjects did not show these changes

In a study of 1068 aged persons who were residents of a home for the aged, Kornzweig *et al* (1957) found cataract formation of all degrees in 61 per cent of the group Of those under 80, 52 per cent had some degree of cataract formation, while of those over 80, the incidence in creased to 76 per cent. Slataper (1950) found no subjects with clear lenses past age 87

Disease of the macula was present in 29 3 per cent of the subjects studied by Kornzweig *et al* The percentage increased with age being 24 1 per cent and 38 6 per cent for those under and over 80 years of age respectively Classification of the mac ular diseases showed 78 6 per cent to be senile 11 1 per cent to be diabetic, and the remainder miscellaneous in type

As to the incidence of other changes Kornzweig (1951), in a study of 125 eyes from 92 individuals ranging in age from 60 to over 90 noted the following

1 Cystic degeneration at the ora serrata (cysts found ruptured in five cases) 101 eyes
2 Thickening and acellular structure of arach noid strands around the optic nerve 92
3 Fibrosis and hyalinization of fibers of cili ary muscle and hyalinization of the stroma of the ciliary process 83
4 Hyaline bodies of lamina vitrea 80
5 Opacification of lens fibers (incipient cata ract) 62
6 Sclerosis of arteries choroidal 56 central retinal artery and branches 51 major ar terial circle of iris and iris artery 40
7 Pigment granules in trabeculae of anterior chamber 50
8 Widening of supraciliary space (ante or post mortem?) 46
9 Papillary proliferation of pigment layer of pars plana 24
10 Cystic separation of non pigmented from pigmented epithelium of pars plana 14
11 Hyaline thickening of Descemet s mem brane (Henle s warts) 5

12 Hyalinization of subsphincteric tissue of iris 5

Duke Elder (1941), in writing about the retina, stated

> In the aged, the retina shows less marked evidences of senility than most tissues As a whole it becomes less transparent owing largely to an increase in the neuroglial elements, a process which is associated with a parallel tendency to atrophy of the neural elements [These changes start at the periphery and are] most marked in the inner layer which show a progressive atrophy of the nerve fiber layer, the ganglion cells and the inner nuclear layer [pp 2745–46]

He believed that these changes were due to diffuse atherosclerosis, but he cited no evidence in support of this statement Towers (1955), in a general description of funduscopic changes with age, also pointed out that retinal changes were usually slight

Fuchs (1920) studied the optic nerve, tract, and chiasm of six persons between 70 and 82 years of age He found many corpora amylacea distributed throughout, which displaced or replaced considerable numbers of nerve fibers He also found foci of atrophy, with extensions more marked centrally than peripherally These he attributed to circulatory disturbances

It is thus evident that many structures of the eye change with age Some functional and some structural changes have proved to be related, many others remain to be explored

Intensity Sensitivity

DARK ADAPTATION

That the final dark adapted threshold increases with age has been repeatedly demonstrated The data of Birren *et al* (1948), which are typical, are shown in Figure 5

Summarizing the general trend of the data shown in Figure 5, and those of Steven (1946) and of McFarland and Fisher (1955), there appears to be a slight drop in log threshold up to the end of the second decade and then a gradually accelerating rise in log threshold, the increase becoming rather marked past the sixth decade Since all three experiments controlled for pupillary changes with age, these changes in threshold cannot be attributed to the decrease in pupil size with age Combining the data of McFarland and Fisher with those of Birren and Shock (1950), it is evident that a similar pattern holds for age changes in final cone thresholds Hecht and Mandelbaum (1939) found that cone threshold rose more with

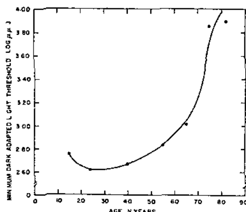


FIG 5—The minimum dark adapted light threshold as a function of age (Adapted from Birren *et al*, 1948)

age than rod threshold, indicating that the yellowing of the lens with age could not account for all the change, at least in the cone threshold Birren and Shock found no correlation between age and rate of either cone or rod adaptation, although there was a significant but low positive correlation between cone rod transition time and age McFarland and Fisher also found no age change in rate of dark adaptation Final rod thresholds were obtained by Birren *et al* (1948) in eight subjects under 30 and thirteen subjects over 50 with both violet and white light They found that use of the white light changed the thresholds of the old and young 1 29 and 1 44 micromicrolamberts, respectively, indicating that the age related threshold differences

could not be attributed to the use of violet light Sharpley (1948) noted that the presence of nystagmus did not affect the elevation of final dark adapted thresholds

ELECTRICAL SENSITIVITY

Another method of measuring the sensitivity of the eye has been by means of electrically induced phosphenes Verkhutina and Efimov (1947) measured the minimum electric direct current necessary to elicit a phosphene in subjects ranging in age from 5 to 79 years They converted the threshold figures into reciprocals which they called the electrical sensitivity Their results are shown in Figure 6 These measurements were performed in darkness with one electrode held over the closed eye, and the other electrode held in the contralateral hand The electrical sensitivity of the eye can be seen to increase from ages 5–7 to ages 25–29 and thereafter to decrease to about ages 50–59 In a later experiment Semenovskaia and Verkhutina (1949) made similar measurements after a 3 minute period of light adaptation to a white screen of 140 lux brightness The mean electrical thresholds in microamperes and the range of distribution for each age grouping are shown in Figure 7 The threshold drops rapidly from age 6 to reach a minimum at about age 20 It then rises very slightly to about 45 years and then more steeply

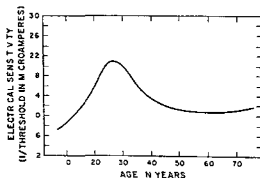


FIG 6—Electrical sensitivity of the dark adapted eye as a function of age (After Verkhutina and Efimov 1947)

Comparing this plot of electrical threshold to the plot of light threshold shown in Figure 5 the curves appear to be quite similar up to about 50 years of age, after which the light threshold rises much more steeply However, in both of the experiments on electrical sensitivity, the numbers of subjects in each of the age groups over 30 were too small to allow more than a general comparison of their curve shape with that from the light threshold data The most important similarity lies in the peaking of the curves in the third decade

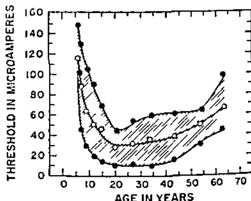


FIG 7—Threshold of the light adapted eye to electrical stimulation as a function of age (After Semenovskaia and Verkhutina 1949)

DIFFERENCE THRESHOLDS AND CONTRAST SENSITIVITY

There are few data available on changes in visual difference thresholds with age Gregory (1957) obtained some data on a small number of subjects, his results are shown in Figure 8 As is explained in the legend the two graphs were obtained by different methods The important fact brought out by these graphs is that the Weber fraction increases with age, particularly after the fifth decade If the changes in vision with age are simply such as to produce an attenuation of intensity of the light reaching the retina the slope of the curves would not change The curve would simply be displaced upward, changing the *y* intercept However, the differ

ences in slope obtained by the two methods especially in the older groups, should not be overlooked A related finding of a reduction in the number of JND's (just noticeable differences) with age was reported by Zinner (1930) He found that astronomers over age 50 could not differentiate as many brightness classifications of stars as younger workers The change of the Weber ratio with age is highly important and will be extensively discussed toward the end of this chapter

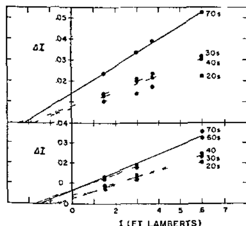


FIG 8—These two graphs show the relation between ΔI and I fitted by the method of least sqares for the age groups indicated for each curve Different psychophysical methods of determining the differential intensity threshold have been used The top graph gives data where the signal field ($\Delta I + I$) is a flash of duration 0 04 second the intensity being adjusted to an 80 per cent criterion The bottom graph shows data where the signal field was adjusted continuously by the subjects to be just visible

White light was used the intensity units being foot lamberts The background field (I) subtended 15° the signal field ($\Delta I + I$) subtended 5° Foveal fixation was used throughout (After Gregory 1957)

Contrast sensitivity is a form of difference threshold Bouma (1947) had shown that the contrast sensitivity (brightness/delta brightness) at a level of brightness of 0 3 candle/square meter without glare was about 24 from ages 20 to 30 and then dropped to about 17 at age 50 as is shown in Figure 9 In the presence of a strong source of glare the contrast sensitivity was about 3 3 at age 18 and showed a decelerating decrease to about 1 8 at age 50 In an earlier paper, Bouma (1936) found that the reduction in contrast sensitivity between age 18 and 50 was 1 48 without glare, 1 57 with a sodium light source of glare, and 1 69 with a white-light (incandescent) source of glare As sodium light has very little blue in it, it is conceivable

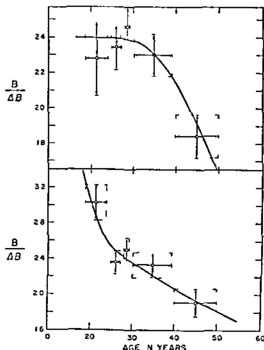


FIG 9—Average contrast sensitivity as a function of age measured at a level of brightness of 0 3 candle/square meter *Upper figure* no source of glare *lower figure* with a strong source of glare (After Bouma 1947)

that the increased contrast sensitivity reduction with white light as compared with sodium light may be due to fluorescence effects of the blue portion of the white light on older lenses

Guth *et al* (1956) studied the effects of intensity of illumination on the reading of 6 point type through the Luckiesh Moss Visibility Meter in a hundred subjects ranging in age from 17 to 65 years They found that older subjects required higher in

tensities of light to obtain the same degree of visibility as younger subjects (All subjects had been refracted beforehand to eliminate effects of refraction differences and all subjects were permitted to become acquainted with the words to be used in order to eliminate learning) They found that increasing the intensity of light produced a greater relative improvement for the older subjects This corroborated the findings of Weston (1949) who had studied visual

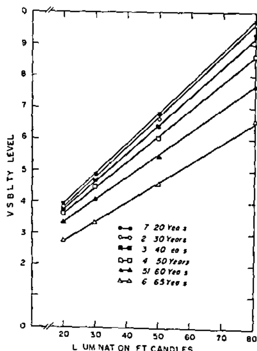


Fig 10 —The relationship between illumination and v s bil ty le el for different age groups (Adapted from Guth *et al* 1956)

performance as a function of age and illumination However in plotting visibility level as a function of illumination as has been done for the data of Guth *et al* in Figure 10 it becomes evident that older subjects require a greater absolute increase in intensity of light than the young to achieve an equal improvement in visibility level This change of slope with age is qualitatively similar to that described for difference thresholds and will be discussed later

Color Vision

The effects of lenticular changes on color vision have been described already The yellowing of the lens with age acts to filter out the shorter wave lengths Obi (1954) reported that older people required an increased intensity of green light to obtain yellow by mixing green and red The area of Rayleigh s equation was also widened with age Rydin (1927) tested ninety two subjects between the ages of 50 and 95 years by means of a polarized anomaloscope with rays of green and blue green He found that the ability to distinguish between these two colors diminished with age even in the absence of ocular defects but that this change was not discernible below 60 years of age Ferrara (1941) tested twenty subjects between 18 and 38 years twenty subjects between 43 and 67 years and ten aphakik subjects ranging in age from 22 to 68 years His method was to mix a variable amount of blue light with a fixed amount of white light. He found that the older group required more blue light than the young group to evoke a sensation of blue The ten aphakik subjects required less blue light than the young group despite the fact that the median age of the group was 57 5 years He failed to comment on the fact that his four subjects under 55 years all required less blue light than his six subjects 55 years old and over This might indicate a decreased retinal sensitivity to blue with age but his sample of aphakik subjects was too small to allow a reliable statistical test of age difference

A large scale study of age changes in color vision was reported by Janouskova (1955) in which pseudo isochromatic tables were used in children and a matching procedure using Ostwald s color circle was used in adults from 50 to 85 years of age Of particular interest were 180 older subjects who had a distinct yellowing of the lens in one eye and were aphakik in the other In the shorter wave lengths the aphakik eyes were distinctly different from

their mates However, in the region of red and green, the disturbance was present in both eyes This indicates that the disturbance in color vision accompanying old age cannot be attributed solely to the presence of lenticular changes

Schenk and Pfeifer (1957) studied senile pigmentation of the retina, a not uncommon condition Perimetry with a 5 mm object showed normal fields with a white object and a definite inversion of the color fields of red, blue, green and yellow The dark adaptation curves were within normal range for the subjects' ages

There have been a number of papers on changes in color vision with age (Tiffin and Kuhn, 1942, Smith, 1943, Boice *et al*, 1948, Chapanis, 1950, Kleemeier, 1952, Gilbert, 1957) As the results indicated that other than purely sensory changes were involved, these papers are discussed in chapter xvi

In summary, although no clear conclusions can be drawn from the somewhat contradictory reports, certain indications of age changes in color vision emerge (1) There is a tendency of the lens to yellow around the sixth decade, which serves to diminish transmission of the wave lengths from green to violet Changes in transmission of the longer wave lengths have not been clearly demonstrated (2) There is a reduction in sensitivity of the retina or central structures to blue light and possibly to the green and red parts of the spectrum as well

Critical Flicker Fusion

The decline of critical flicker fusion (CFF) with age has been clearly demonstrated (Simonson *et al*, 1941, Brozek and Keys, 1945, Misiak, 1947) In order to assess the role of pupillary change in this decline, Weekers and Roussel (1946) tested a wide age range of subjects both with and without mydriasis They had five subjects per decade and used a duty cycle of 0 5, brightness of 60 lux Subjects were tested after dark adaptation Their results are shown in Table 4.

When the pupils were not dilated, the CFF declined rather markedly after the fourth decade and then tended to level off after the sixth decade When the pupils were dilated, CFF declined a little from the third through the fifth decades and then declined more rapidly It is evident from these data that decrease in pupil size with age is an extremely important factor in the decline of CFF Miles (1950) and Misiak (1951) also pointed out the effect of pupillary age changes on CFF It is possible that the decline past the fifth decade may be due partly to decreased transmission of light by the lens Coppinger (1955) obtained CFF in 120 white males, ranging in age from 20 to 79 years, at three different levels of stimulus brightness His analysis of variance showed that the slopes of the different age groups were significantly different His data have been plotted in Figure 11 Except for the 60–69 year-old group, the slopes show an accelerating decrease with age This means that older subjects obtain a smaller rise in CFF with increasing brightness than younger subjects A reduction of the amount of light reaching the retina due to lenticular or other preretinal changes would not be expected to change the slopes of the curves This finding will be discussed further later in this chapter.

TABLE 4*

EFFECT OF AGE AND PUPIL SIZE ON CRITICAL FLICKER FUSION

Age	Critical Flicker Fusion	
	Pupils Not Dilated	Pupils Dilated
20–30	40 2	42 8
31–40	39 2	42 6
41–50	34 4	42 6
51–60	31 8	40 8
61–70	31 6	38 4

* Source Weekers and Roussel (1946)

Further evidence for retinal or central loci of CFF change with age is found in the data of Semenovskaia and Verkhutina (1949) Their measurements of the electrical sensitivity of the eye were mentioned earlier Using a current three times the threshold value for each subject they pulsed the current with an 0 5 duty cycle, at an increasing rate to the point of disappearance of phosphene flicker Their results are shown in Figure 12 which gives mean values and range for each age group

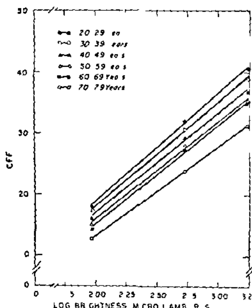


Fig 11 —The relationship between brightness and critical flicker fusion for different age groups (Adapted from Coppinger 1955)

There is a striking correspondence between their mean values and the values obtained by Weekers and Roussel for CFF with pupils dilated Semenovskaia and Struchkov (1952) have described their electrical method in detail

In summary although preretinal factors contribute to the decline in CFF with age, retinal and/or central factors are clearly implicated

Visual Fields

Ferree *et al* (1929*b*) studied visual fields by means of perimetry in two hundred subjects ranging in age from 8 to 56 years They used a test object subtending a visual angle of 1° with an illumination of 7 foot candles They found a reduction in breadth of form field with age, being 67 0° in the second decade, 67 5° in the third decade 66 8° in the fourth decade, 64 8° in the fifth decade, and 64 7° in the sixth decade They found a product moment correlation of − 31 ± 04 between average size of field and age, this correlation was significant at the 01 level No sex differences were found However, their lack of control of visual acuity and effective retinal illumination makes it impossible to

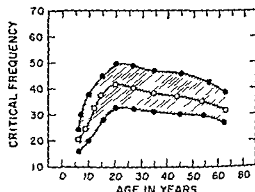


Fig 12 —Functional mobility (critical frequency of electrical phosphene disappearance) of the visual apparatus as a function of age (After Semenovskaia and Verkhutina 1949)

ascertain if the age changes which they found were actually due to a reduction in visual fields Their findings on changes in color fields are subject to similar reservations (Ferree *et al*, 1929*a*) They found that color fields decrease in order from emmetropes to hyperopes to myopes to presbyopes Therefore, the effect of acuity changes cannot be disregarded in their findings on field changes with age The work of Schenk and Pfeifer (1957) (see above) showed changes only in the color fields

Mann and Sharpley (1947) also found a decrease in the visual field with age, but they suggested that their finding might have been due to differences in effective

retinal illumination from pupillary and lenticular differences However, they found that older subjects often showed evidence of absolute or relative scotomata in the mid periphery or further out Ophthalmoscopic examination rarely showed anything of note in these cases

Østerberg (1933) tested the peripheral limits of the dark adapted eye at various levels of illumination He found a slight, gradual decrease in concentric visual field area with decreasing illumination He tested only eight younger and five older subjects, so that generalizations may not be warranted However, he found little if any age difference in field size at higher illuminations In the old the field seems to decrease more rapidly with decreasing illumination This may relate to the higher absolute threshold of the older group

Lange (1952) used intermittent light stimuli with perimetry to find thresholds under conditions of dark adaptation and of very dim illumination He had 21 subjects, ranging in age from 14 to 60 years There seems to be a uniform rise in threshold with age within the perimeter tested (30°) This corresponds to the findings of Weekers and Roussel (1945) in normal subjects aged 20–50 with CFF within the same perimeter

Whether or not the visual field changes with age has not been established In conditions of extremely low illumination the reduced sensitivity of the older eye will produce a constricted field, but there is no indication of field change under photopic conditions

Electrophysiology

Age changes in the *b* wave of the electroretinogram have been studied by Karpe *et al* (1950) Setting rather rigid clinical standards, 74 healthy eyes of 40 subjects over 50 years of age were selected for study Pupils were dilated with homatropine and subjects were dark adapted prior to testing Using a stimulus intensity of 20 meter candles, he found a decline in *b* wave potential with age The decline was small up to the sixth decade and became marked in the seventh decade

Age changes in the *a* wave of the electroretinogram have been studied by Weiss (1956*b*) He tested one eye from each of 26 healthy male subjects, 10 between 18 and 37 years of age and 15 between 66 and 76 years of age Pupils were dilated with neosynephrin, and eyes were dark adapted for 10 minutes A gas discharge flash lamp was used at three intensities Variance analysis indicated that latency varied significantly with stimulus intensity, but there were no significant age differences and no significant age and intensity interaction Graphs of peak times for a_1, a_2 and h_1 and peak amplitudes of a_1 and a_2 indicated a similar absence of age difference, although means showed slight decreases in amplitudes and increases in latencies and peak times for the old Since the slopes of the curves of each variable as a function of stimulus intensity were essentially the same for both age groups, the slight mean shifts may well have been due to somewhat decreased light transmission by preretinal structures in the old This may also account for the findings of Karpe *et al* (1950)

Miles (1939) measured the steady polarity potential of the eye in three groups of female subjects, twenty aged 10–12 years twenty aged 17–19 years, and sixteen aged 41 65 years He found mean values of 1 11 mv 1 20 mv, and 1 09 mv in these groups, respectively, using bitemporal leads, with the eyes deviated 30° laterally He found no correlation between body potentials and eye potentials The body potentials were balanced out with a counter-electromotive force prior to measurement of eye potentials

In summary, although the electroretinogram data seem to indicate some diminution of response with age, it is not clear if these changes are due to retinal or preretinal factors The apparent rise and decline of the steady potential of the eye with age are unexplained

III AUDITION

The incidence of socially recognized hearing impairment was discussed in the first section of this chapter The nature of such impairment may be due to a variety of factors both peripheral and central Central impairment is of a perceptual nature and will be discussed in chapter xvi This chapter will confine itself to hearing changes attributable to the ear and the auditory nerve

per frequency threshold Therefore a determination of absolute limits would require testing at sound pressure levels up to the threshold of an undifferentiable sensation The values shown in Figure 13 are consequently only relative to the submaximal sound pressure levels that were used

Of particular interest is the similarity of decline in both air and bone conduction as shown by Gildemeister This may indicate that the decline in upper frequency limits was not due to conductive defects

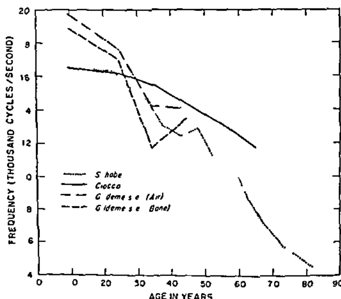


FIG 13 —The upper frequency limits of hearing as a function of age. (Adapted from Gildemeister 1908 Ciocco 1932 and Schober 1952)

Changes in the Frequency Spectrum

The main change in the limits of the audible frequency spectrum with age occurs in the upper range The results of three different studies are shown in Figure 13 (Gildemeister 1908 Ciocco 1932, Schober 1952) Each of the three authors used a different method but the results of each showed a decline in the upper limit of hearing with age The differences in the slopes of the curves may have been due to differences in the methods used

Gildemeister showed that increasing the sound pressure levels would raise the up in the middle or outer ears of his subjects. Ciocco found no sex differences in his data

THRESHOLD ACUITY

There have been many studies of the rise of auditory thresholds with age (e g Montgomery 1932 Steinberg *et al*, 1940 O Neill 1956) Since many of these used unselected subjects it was difficult to separate changes due to aging from those due to other factors A study of 360 subjects all carefully selected for absence of known pathology, was performed by Rosee (1953) His results are shown in Figure 14

There appears to be a small, regular increase in hearing loss throughout the frequency spectrum up to ages 21–25. Above this age range, a disproportionately increasing loss at the higher frequencies becomes apparent, compared to the small increase in loss at the lower frequencies. The *ranges of amount of loss increase with age*, especially at the higher frequencies. However, all subjects over 41 years showed at least a 10-db hearing loss at the highest frequency. All subjects over 70 years showed over a 10-db loss at all frequencies.

These subjects showed no more than 10-db differences between air and bone conduction, indicating that the hearing loss was not of the conductive type. In support of this, the Rinne test with an a^1 tuning fork was positive in all subjects (i.e., air conduction always exceeded bone conduction). Ciocco (1935) found a disproportionate shortening of bone conduction with age in subjects with good air-conduction hearing up to 512 cps, in agreement with the findings of Rosée.

As regards sex differences, Bunch and Raiford (1931) found that males of all ages (range from 20 to over 60 years) heard better than females at frequencies lower than 2000 cps, while the reverse held for the higher frequencies. Males showed a dip in acuity around 4000 cps.

Acuity for forced whisper also diminishes with age. Rosée found that whispering heard at or beyond 10 meters by subjects under 50 years of age was heard at 8–10 meters by the 51–55 year group, at 6–8 meters by the 56–60-year group, at 5–7 meters by the 61–65 year group, at 3–5 meters by the 66–70-year group, and at 1–4 meters by the over 71 year-old group.

In a longitudinal study of the relation of occupational noise exposure to loss of hearing acuity, Pell (1957) found that 5 years of steady state occupational noise produced more impairment in older people with little or no loss than in younger people with similar initial loss, and the effect was more pronounced the higher the noise level. The lack of sex difference below age 55 found by Beasley (1940), as shown in Table 2, supports these findings. A similar increased susceptibility to hearing damage with age was suggested by Witchell (1956) on the basis of audiometric studies after prolonged streptomycin therapy, but the lack of pretreatment audiograms precludes any definitive conclusion.

SUPRATHRESHOLD ACUITY

In a study of 185 old subjects, Pestalozza and Shore (1955) found that discrimination for speech was poor, even in the presence of only a mild hearing loss by tone threshold audiometry. A parallel investigation of young individuals with the same amount and characteristics of hearing loss found no comparable discrimination loss. In the aged the slopes of the audiogram were not significantly related to discrimination loss. The relation between hearing loss for pure tones, hearing loss for spondees, slope of audiogram, and discrimination loss showed that subjects with a steep slope of the audiogram (more than 20 db per octave) had a smaller hearing loss for spondees than could be predicted from the audiogram when compared to subjects with flat or mild slopes. Since these

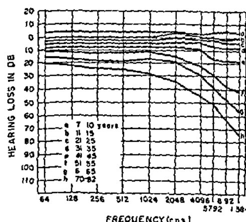


FIG 14—Mean hearing loss over the audiometric frequency spectrum for different age groups (From Rosée, 1953)

relationships were much more precise in the young subjects, the authors suggested that there was a "phonemic regression" syndrome in the aged, which probably had a non peripheral basis

These authors also tested twenty four aged subjects for recruitment They found that 50 per cent showed no recruitment, 30 per cent partial recruitment, and 20 per cent almost complete recruitment

A lack of recruitment in presbycusis was also found by Bruine Altes (1946) in four

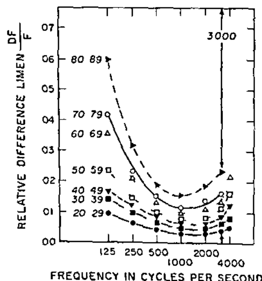


FIG 15 —Relative difference limen for pitch as a function of frequency for different age groups De terminations made at sensation levels of 40 db above threshold (After Konig 1957)

subjects Fleischer (1956*b*) studied 59 sub jects who had been selected for normal hearing by the criteria of Rosee Among the 22 subjects who were over 59 years of age, nine showed reduced difference limen, viz, presence of recruitment No recruit ment was found in the 37 subjects under 60 years of age In 111 subjects, Fleischer used the method of Langenbeck to study tone thresholds in the presence of noise masking He obtained thresholds under two noise intensities for each subject, using either 50 and 70 db or 60 and 80 db In the normal the difference threshold is not over 5 db, in the "ganglion type" there is 10 db or more difference, while in the 'hair cell type" the curves cross The per centage of normals decreased with age, while the "ganglion types" increased with age There were too few "hair cell types' to allow any conclusion regarding age dis tribution He concluded from these results that the basis for presbycusis lies in gan glion cells of the inner ear

Using speech audiometry in 104 subjects, Fleischer found no cases of impairment below age 50, with increasing percentage of subjects over 50 showing impairment Two types emerged in the aged group

curve with increasing intensity

Using 60 db noise masking with speech audiometry, no subjects under 50 years showed loss, while older subjects showed both P and R types of loss, the percentage of subjects showing loss increasing with age This tendency became more pronounced with 80 db noise masking, where even some subjects in the 40–49 year-old group showed some loss It is not clear if the speech audiometry data indicate peripheral or central impairment with age, although Fleischer favors a central locus Unfortunately, all tests were not carried out on the same subjects, thus it is not possible to correlate the various test findings

Frequency Discrimination

In a study of pitch discrimination and age Konig (1957) found that pitch dis crimination performance deteriorated in an approximately linear fashion from ages 25

ward the higher frequencies These changes may well affect speech comprehension, it would be necessary to test the same sub-

jects for pure tone threshold, frequency difference limen, and speech comprehension in order to separate the relative contributions of these factors

Temporal Discrimination

The ear is a temporal as well as a frequency and intensity analyzer Weiss and Birren (1957) studied the time interval at which two 0 25 millisecond clicks at 30 db

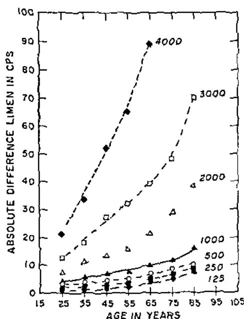


FIG 16 —Absolute difference limen for pitch as a function of age at different frequencies Determinations made at sensation levels of 40 db above threshold (After Konig 1957)

above threshold could be discriminated from one such click Testing 15 young males and 27 healthy males over 65, they found that the medians of the two groups did not differ significantly by the median test However, the *Mann Whitney U* test was significant at the 05 level The medians and interquartile ranges are shown in Table 5 The difference between the old and young groups seems to lie in the distribution, with the Q_3's being the only values to differ substantially

Each subject's intensity threshold to 1 click per second and 2000 clicks per second were obtained, audiograms were also made In a correlation analysis of the values of the old subjects, the click thresholds and the audiographic 2000 cps tone threshold showed high degrees of correlations However, none of these correlated with the 2-click discrimination threshold Apparently, the factors involved in age changes of intensity threshold and those involved in temporal discrimination are not significantly related Subjects were also required to judge numbers of clicks, which were from 1 to 10 in number and varied in the rate of delivery from 6 25 to 15 87 clicks per

TABLE 5*

TWO CLICK DISCRIMINATION AND AGE

(In Milliseconds)

Group	No of Subjects	Median	Q	Q_3
Young	15	1 80	0 86	2 77
Old	27	1 72	1 35	5 56

Median test p = not significant
Mann Whitney U test p = 0.548

Source Weiss and Birren (1957)

second On the whole, older subjects reported significantly fewer clicks than younger subjects, although both showed some loss No correlation between this measure of perception and 2 click discrimination was found in the older group, indicating that auditory temporal discrimination and auditory perceptual judgment changed differently with age

Anatomic Changes

On the basis of rather limited studies, Mayer (1920) attributed presbycusis to an increasing rigidity of the basilar membrane, but later workers have not generally supported this conclusion

In an extensive study which included clinical examination, audiograms, and path-

ological examination of the cochlea and middle ear, Crowe *et al* (1934) found a fair correspondence between high tone loss and evidence of pathology in the lower turn of the cochlea They described two types of hearing loss, the "gradual' and the 'abrupt', these were differentiated on the steepness of slope of the hearing loss audiogram Nearly all the gradual type showed primarily loss of nerve fibers, usually without great changes in the organ of Corti Twenty of the 24 of these ears were from individuals 59 years or older, the four younger subjects showed the least nerve fiber losses

Most ears with abrupt type loss showed organ of Corti changes with accompanying nerve fiber losses These ears were spread throughout the age spectrum, 18 ears coming from individuals under 60, and 6 coming from individuals over 60 years of age The control group of normal hearing ears all came from individuals under 60, these showed no great pathology Six of the 17 ears showing gradual type hearing loss without much pathology were over 60, and 11 were under 60 As a group, these showed only slightly more nerve-fiber loss than the control group The hearing loss found in these ears may have been due to more central pathology or to peripheral changes not discovered by the histological techniques that were used

In a clinical and pathological study of presbycusis Saxen (1937) described two

nerve fibrils, chiefly affect the proximal parts of the cochlea The epithelial parts of the cochlear duct, especially the organ of Corti with its sensory cells, are not included in the process, neither do alterations in the blood vessels of the inner ear characterize this disease Histologically the atrophy of the nerve elements in the cochlea corresponds to the clinical picture of presbycusis" The angiosclerotic degeneration of the inner ear he considered to be a consequence of vascular sclerosis, characterized by a regressive metamorphosis of the epithelial part of the ductus cochlearis. He did not find any important functional changes associated with this pathology alone as tested with standard tuning forks Of his 33 cases 13 showed senile atrophy and 19 showed angiosclerosis The one other case showed no pathology, he surmised that the presbycusis in that case was probably of central origin

Fleischer (1956*a*, 1956*b*) studied histological preparations of a hundred ears from individuals ranging in age from birth to 91 years The striking finding was the decrease in ganglion cells in the basal turn of the cochlea, which was small up to about age 50 and became more marked with increasing age The losses in the middle turn of the cochlea were much less marked

Schuknecht (1955) attributed presbycu One he termed

changes

rinth including afferent and efferent nerve fibers, which began at the basal end and proceeded toward the apex He found good correspondence between these changes and audiographic measurements in four cats (The audiograms were obtained by a conditioning technique) The second type he termed "neural atrophy," in which there was a decrease in population of neurons of the auditory nervous pathway and which he thought, was usually superimposed on epithelial type atrophy Here he found a fair correspondence between ganglion cell loss and audiographic changes Both of these types differed from the type of hearing loss found in trauma and in various infectious diseases He found no correlation between cochlear and vascular changes

Covell and Rogers (1957) studied the ears of thirteen guinea pigs ranging in age from 1 year and 356 days to 4 years and 209 days and of sixteen young controls

The predominant pathologic change in sections through the cochleas of the senile animals was the smaller number of gan glion cells, a change most apparent in the apex and somewhat less so near the base of the first turn The intervening turns were generally normal, the three oldest animals and one 848 day old showing some changes

The loss of peripheral nerve fibers accom panies the degenerative processes associated with the spiral ganglion cells Degeneration of the proximal and distal fibers of the bipolar cells proceeds in each direction and the last myelin sheath to disappear distally is in the re gion of the habenula perforata or centrally in the substance of the cochlear nerve, thus it does not seem to precede the loss of ganglion cells but instead follows it This is somewhat contrary to the present concept of the sequence of events for other factors such as acoustic trauma resulting in similar pathologic changes

Degenerative changes in the organ of Corti are not a predominant feature in the earlier stages of senile changes They do, however be come more prominent with increase in age of the animal and only for those turns associated with marked loss of spiral ganglion cells

The stria vascularis was without pathologic changes for many of the specimens [Covell and Rogers 1957 pp 122–25]

The findings have been quoted at length because this study was associated with an electrophysiologic study, which will be de scribed below

Electrophysiologic Changes

A study of bioelectric potentials in the ears of senile guinea pigs was carried out by Pestalozza *et al* (*1957*) An earlier re port of this study which gave some addi tional information was made by Pestalozza (1957) These studies were undertaken in conjunction with the anatomical studies of Covell and Rogers, which were quoted ear lier Pestalozza and his co workers meas ured the voltage across the condenser mi crophone necessary to produce a 3 micro volt response in the component being meas ured They found that the cochlear mi crophonic potentials (CMP) changed least with age, four to six of the twelve old animals had values within normal limits Furthermore, in the cases in which CMP were diminished, the diminution usually extended to the whole tonal auditory range The nerve action potentials (AP) showed the greatest diminution with age, while the summating potentials (SP) were intermediate between the CMP and AP The diminution of response was most marked for the high frequencies, some times with considerable lowering of the upper limit, and it was often evident for frequencies below 4000, down to 500 cps

In pure conductive loss, higher micro phone voltages would be necessary to elicit the normal CMP, but the relations of CMP, SP and AP would be normal In the senile animals, however, a disproportionately large CMP was required to elicit the normal AP, indicating neurological deficit

Comparison of the diminution of electri cal responses and the histomorphological alterations revealed that the latter were always of more modest extent than the former

In summary, it would appear that audi tory sensory changes associated with aging are characterized by a gradual high frequen cy loss, which will gradually restrict the up per frequency limit of hearing Low fre quencies are much less affected and only later in life Recruitment does not seem to be characteristic of presbycusis There may be a rise in difference limen as meas ured by tone thresholds in the presence of masking noise Both bone and air conduc tion thresholds rise There may be an im pairment of temporal discrimination, there is certainly a progressive impairment of speech discrimination To what extent these changes are due to peripheral as opposed to central changes is not clear A good review of this subject has been made by Altmann (1955)

The primary pathology in the periphery seems to be the atrophy and disappearance of ganglion cells, with possible subsequent degeneration of the hair cells in the organ

of Corti The electrophysiologic finding of a disproportionate diminution of nerve action potentials compared to cochlear microphonic potentials is in agreement with these histological data

IV VESTIBULAR FUNCTIONS

Mechanical and Caloric Stimulation

Age changes in vestibular functions have received only scant attention in the literature Although increase in vertigo with age has been reported (Droller and Pemberton 1953 Orma and Koskenoja 1957) it s not known if the vestibular mechanism is involved

Okano (1938) tested 223 relatively healthy subjects ranging in age from 60 to over 80 years He found that postrotatory nystagmus was nearly always present in the seventh and eighth decades and absent in 10 per cent of subjects in the ninth decade The duration of nystagmus decreased gradually with age as did the number of jerks There was an increase in coarse nystagmus particularly in the ninth decade Side effects such as nausea and headache decreased in incidence with age Testing caloric nystagmus he found a decrease in incidence and magnitude with age with cold stimulation Latency increased while duration and number of jerks decreased Coarse nystagmus also decreased With heat stimulation he found an increase in latency with a slight tendency toward decreased duration and number of jerks He stated that subjects with normal blood pressure tended to show more normal

states

117 subjects without ear disturbances and with ages about equally distributed between 10 and 63 years were (1) rotated 10 times in 20 seconds (2) subjected to a caloric examination according to Kobrak In the rotation nystagmus duration and frequency increased up to 45 years and declined slightly after this age In the caloric nystagmus, latency and duration were independent of age but frequency showed a peak at 45 to 50 years Thus the labyrinth as far as nystagmus is concerned, seems to be most responsive in the fifth decade

Arslan (1957) studied fifty subjects between the ages of 49 and 84 years by Veits s method of thermal stimulation He found that the number of jerks and the duration of the nystagmus showed parallel behavior Since the values obtained in this group did not differ markedly from those obtained in average normals, he reported the distribution of subjects in terms of falling within or outside of ±1 standard deviation He found that thirty subjects fell below −1 S D six fell above +1 S D and fourteen fell within ±1 S D These results would indicate a shift of the older population toward vestibular hypoexcitability He studied the postrotatory nystagmus in ten of these subjects by means of the Buys Fischer Arslan method Five subjects showed normal excitability, and five showed moderate hypoexcitability

Allard (1938), comparing the duration of rotation necessary to produce one post rotatory nystagmic jerk in sixty subjects between 20 and 25 years of age and in six subjects over 60 found a decreased sensitivity in the older subjects However, the sample of older subjects was too small to be conclusive

For the purpose of testing the efficacy

jects of various age, ranging from under 20 to over 40 years Unfortunately, the over 40 group was not more clearly separated

Guedry (1950) compared the subjective duration of postrotational effects of two groups one ranging from 19 to 21 years the other from 30 to 53 years The older group showed a significantly longer subjective duration of effect

Electrical Stimulation

Bourliere (1948) measured the chronax ie of electrical vestibular stimulation by the monoauricular method in 160 subjects ranging in age from 20 to 84 years Al though the author concluded that he found no age change, it would appear that the chronaxie was fairly constant from the third through the sixth decades and in creased slightly but significantly thereafter (t tests give p values of less than 01) In rats, he found that the vestibular chronax ie decreased up to the 25th day and then gradually increased up to 730 days (t test significant at the 01 level)

Anatomic Changes

According to Saxen (1937) Fleischer (1956*a*), and Rasmussen (1940), the ana tomic changes in the vestibular system are minimal However, these studies were not extensive enough to be considered def initive

In summary, age changes in vestibular functions are not well known There may be some decline in vestibular sensitivity in later life perhaps beginning in the sixth or seventh decade

V Taste and Olfaction

Gustatory Sensitivities

Little experimental work has been done with age changes in the sense of taste, re search on structural changes in the gusta tory apparatus will be described later Harris and Kalmus (1950) studied thresh old sensitivity to phenylthiourea in 441 subjects of various ages, ranging from 10 to over 70 years Sensitivity to phenyl thiourea is known to be genetically deter mined showing a bimodal distribution for threshold concentration They found an in crease in threshold for both ' tasters" and non tasters ' with age, with the regression coefficient for the whole series being 0577 ± 006 Dividing their subjects into four age groups, 10–29, 30–49, 50–69, and 70 and over years, the mean dilution factors were 7 527, 6 098, 6 125, and 5 560, respectively The proportion of tasters and non tasters did not differ among the groups Females showed slightly lower thresholds than males in both taster and non taster groups

Richter and Campbell (1940), in testing the threshold for sugar, found two separate thresholds one in which the test solution merely tasted different from water, and one in which a definite sweet taste was recognized Both the difference and the sugar-taste thresholds showed a decrease from childhood (ages 7–10) to adulthood (ages 19–50) but increased to a much higher level in the oldest group (52–85 years) The difference thresholds were 0 44 0 17, and 1 23 per cent, respectively, while the sugar taste thresholds were 0 68, 0 41, and 1 23 per cent, respectively A similar rise in sugar threshold with age was found in bees by Frisch (1934)

Bourliere *et al* (1958) studied the ef fects of age on perception and recognition thresholds for sugar and salt Their findings for sugar thresholds were similar to those of Richter and Campbell For salty tastes, they found that only the threshold of per ception increased with age and that only in men The threshold of recognition in men was higher than that in women at all ages

Structural Changes in the Gustatory Apparatus

There have been several studies on changes in the number of taste buds per papilla and the number of papillae with age Arey *et al* (1936), combining their data with those of Heiderich, showed that the mean number of buds on the circum vallate papillae between birth and 20 years was constant (245) During maturity and early old age (20–70 years) the number was slightly smaller (208) In extreme old age (74–85 years) the mean dropped to 88, which was probably twice as high as it should have been because the highly

atrophic papillae were not included in the study The mean number of taste buds on the trench wall showed a somewhat different course being 10 for the first year, 18 in the next 2 years and 74 between the fourth and twentieth years The number declined to 48 in maturity and early old age and to 13 or less in extreme old age This study also established that the papillary taste buds were maximal at birth and declined while the taste buds in the trench wall increased in number from birth to the second or third decade before they declined In both cases the decline was most rapid in extreme old age It was also noted that the lateral papillae involuted earlier than the central ones Similar findings were reported by Mochizuki (1937)

Jurisch (1922) found that the number of papillae vallata declined only slightly with age and that individual variation was so large as to make the mean decline be of doubtful significance However the number of double papillae did decline markedly with age Mochizuki (1939), studying the papillae foliata of Japanese persons found that the number of papillae declined slightly from birth to maturity and then remained constant into old age In counting the numbers of taste buds of these papillae he found that the number increased from birth to maturity and then declined in old age

Allara (1939) found that the gustatory papillae became fully developed around puberty and remained largely unchanged until approximately age 45, when they began to show involutional atrophy Interestingly by means of a microincineration technique he also found that the mineral content of gustatory calices and papillae was high in infancy, diminished gradually until puberty and then increased again slowly into old age (Allara 1941)

Moncrieff (1951) described the changes in distribution of taste buds from childhood to maturity as the disappearance of taste buds from the underside and the central dorsum of the tongue the lips, the buccal mucosa the tonsils, and the uvula Taste buds appear in the human fetus at 3 months and are more widespread in the embryo than in the child (p 41) With increasing age, the taste receptors disappear from all but a few localized areas (p 131)

In summary, the data indicate that both sensitivity and the apparatus responsible for taste decline with age, particularly from maturity into old age However, the paucity of data does not permit much generalization on age changes in the sense of taste

Olfactory Sensitivities

The data on age changes in the sense of smell are sparse and contradictory In an early study, Vaschide (1904), using camphor with an osmiesthesimeter of Toulouse and Vaschide, found a marked decline in sensitivity with age with a large increase in the number of anosmic subjects The females showed superiority to the males regardless of age He remarked that very often the anosmic individual was not aware of his defect—the subject often believed that he was smelling something when in fact he was not These results differ from those of Mesolella (1934), who found little if any change with age using the Zwaardemaker olfactometer He also found no superiority of females He attributed the slight degrees of hyposmia which he found to catarrhal symptoms or to the abuse of snuff or smoking tobacco in all but two unexplained cases He concluded that the various degrees of diminution of the sense of smell in the old should be attributed to the destruction of the stratum of Schultze by inflammatory, stenosing, or toxic processes

Moncrieff (1951) stated that olfactory is absent in young mammals whose diet is exclusively maternal milk, and only develops at weaning time In the case of man olfaction is supposed to reach its peak at and soon after, puberty, and to

decline after the age of 45" (p 218) No data were cited in support of these statements

Structural Changes in the Olfactory Apparatus

Mesolella (1934) histologically examined the macula lutea (of the nasal epithelium), olfactory bulb, and hippocampus of mac rosmatic animals, such as rabbits, cats, and dogs, of a few days to an advanced age He compared the results to those found in the olfactory bulbs and maculae luteae of hu mans over 70 years of age who had no evidence of nasal disease These specimens were removed immediately after death In the animals the structures appeared to be fully developed shortly after birth, the old animals showing no significant changes In the five humans, he found atrophy of the bulbs with rarefaction of the nervous ele ments In the maculae, he found exfoliation and disappearance of the covering epithe lium as well as dense infiltration of small cells in the submucosa He concluded that chronic catarrhal conditions must have been responsible for the observed changes In support of this, he cited findings by other experimenters describing the response of the olfactory mucosa to experimental trauma

The work of Smith (1942) supported the finding of atrophy of the bulbs in aged humans He counted glomeruli in 205 bulbs from 121 individuals and estimated the percentage of fiber loss He found a steady progression of fiber loss from 8 per cent at 0–15 years to 73 per cent at 76–91 years The rate at which fibers disappeared was fairly constant at 0 9 per cent per year up to the age of 37, then it rose to 1 6 per cent per year between the ages of 37 to 52, after which it decreased again to 0 7 per cent and, finally, to 0 3 per cent per year in the succeeding two 15 year periods There were no sex differences under the age of 50 It should be noted, however, that there was great variability, some old bulbs showing no atrophy He also suggested that nasal disease as well as age might be a factor in the loss of olfactory nerve fibers

In an earlier study with 71 male albino (Wistar) rats of various ages, Smith (1935) measured the volume of the brain, the olfactory bulb, the olfactory center, and the vomeronasal center After 1 year of age, the olfactory center showed atrophy of the olfactory nerves and the glomerular and outer fiber layers, while the vomer onasal center showed no change The vol ume of the olfactory center increased up to about 1 year and decreased thereafter The vomeronasal center increased up to 1 year and remained constant to about the third year, after which it did decrease slightly The olfactory bulb volume changed *pari passu* with the olfactory-center vol ume The volume of the brain increased up to 1 year and remained constant until the third year, when it decreased slightly (ap prox 3 4 per cent)

In summary, there seems to be a decline in olfactory function with age, paralleled by atrophy of the olfactory organs How much of these changes is due to aging per se is still a controversial point

VI Somesthesis

The bodily sensations have been de scribed by clinicians as commonly being diminished in old age In 1931 Critchley wrote

> It is a common observation that in old age there may be a general diminution in the acuity of perception both as regards the special senses and also in respect of visceral and cutaneous sensation Severe thoracic and abdominal disease exists in the aged without pain, an ex-
>
> ..
>
> surgical operations and dental extractions can be carried out with but little pain and discomfort The catastrophe of coronary thrombosis can take place with none of the agonising symptoms found in younger individuals On the other hand, subjective sensory complaints are relatively common among the aged Thus stab-

bing darting or aching pains may be described particularly in the lower limbs Neuralgias are common Dysaesthesiae of various types are also frequent, again especially in the legs

It is highly probable that postural sensibility is also affected though less frequently and to a less obvious degree

Appreciation of tactile and painful stimuli is also impaired or even lost in a number of very aged individuals though this defect is certainly less common than disorders of deep sensation When present it is almost always found over a characteristic distribution—namely over the hands and distal portions of the arms and over the feet and distal portions of the legs There is no sharp demarcation between normal and impaired sensibility one area merging gradually into the other In many cases there is a relative rise in the threshhold of pain sensibility though not of cold [p 1221]

Qualitative clinical descriptions such as those quoted above are common in the literature although statistics as to the incidence of these clinically observed changes are few Howell (1949) examined 200 healthy old Chelsea pensioners neurologically Regarding sensory changes, he found that only 2 per cent showed any loss of joint sense of position using the great toe On pain, temperature, and light touch he said

The results of examination for these sensations were often very hard to interpret Some times pain and temperature would be diminished over the same area Sometimes one would be normal while the other seemed impaired. Touch was involved only half as often as the other sensations Altogether some 45 patients failed to register 73 sensations between them The findings were most frequent in the age groups between 70 and 85 The sites of anesthesia were fairly constant, being almost always on either the shin or the forearm Usually the inner aspects of the limbs were involved but the distribution seemed to follow more of a cord segmental pattern than to conform to any actual superficial nerve area [In summary] 24% of the men showed impairment of one kind or another Two fifths of these did not register pain two fifths did not register changes in temperature and one fifth could not appreciate light touch

TABLE 6*

PERCENTAGE REGISTERING VIBRATION SENSE

Age	No of Subjects	Wrists		Elbows		Shoulders		Ankles		Shins		Knees		Sacrum
		R	L	R	L	R	L	R	L	R	L	R	L	
65–69	16	100	100	100	100	80	94	87	87	94	87	50	56	12
70–74	57	100	100	100	100	98	98	88	84	81	79	61	67	18
75 79	72	100	100	100	100	90	89	76	73	73	74	51	53	15
80-84	32	97	97	94	97	94	94	62	56	62	44	31	34	10
85–91	9	100	100	100	100	100	100	89	89	67	78	67	78	11
Mean		99	99	98	99	94	94	79	76	75	72	52	56	15

* Source Howell (1949)

Deep pain was not tested His results for vibration sense are shown in Table 6 The numbers are the percentages of subjects showing vibration sense in each of the areas tested There was a trend of increasing absence of vibration sense in the sacrum and lower limbs with age

A clinical study of sensation in the aged which was handled by factor analysis was reported by Kuroiwa *et al* (1951) Using 84 healthy old people and 12 younger controls they performed the following clinical tests (1) threshold value for pain (2) two-point discrimination, (3) threshold value for touch perception, (4) recognition of weight difference, (5) toe discrimination, (6) perception of movement (7) Romberg test, (8) threshold value for electrical stimulus perception, and (9) vi

bration sensation They observed a reduction of function in the aged by all these methods which was particularly marked for tests 1, 2, 3, 8, and 9 and slight for 4, 5, 6, and 7 Statistically, the former group of tests showed age differences significant at the 001 level, the latter group showed significances at the 05 level

Analyzing the results by a centroid solution, they found three comparatively feasible factors of clinical significance

1 The second factor showed a large amount of connection with test methods 2, 4, and 5, and they supposed that it was probably a higher position sensation factor

2 The first factor showed the largest amount of connection with test methods 6, 7, and 9 and was probably a factor related to the deeper sensations Test method 3 had this factor to a considerable extent, and they supposed that this might be due to the fact that the sense of touch goes upward through the dorsal tract of the spinal cord along with the deep sensations They thought it reasonable to consider this a factor of dorsal tract type

3 The third factor showed a large amount of connection with test methods 1 3, and 4 and it probably represented surface sensations They designated it as the lateral tract type factor

The first type sensation (second factor) was thought to be a high position sensation, represented by two point discrimination The second type sensation (first factor) was assumed to be spinal cord dorsal tract type, represented by sensation of movement or the Romberg test The third type sensation (third factor) was assumed to be the spinal cord lateral type, represented by pain threshold

For each factor the aged showed differences from the controls at 001 significance levels Among the various factors, however, there was no difference in the degree of lowering Unfortunately, the report did not give any numerical description of the findings

Cutaneous Sensations

For convenience, all findings related to sensory age changes in exposed epithelial structures will be considered in this section

TOUCH

Ronge (1943*a*) investigated touch, using an aesthesiometer on 2 square centimeters of the ulnar aspect of the volar wrist His subjects were ten males, ranging in age from 12 to 76 years He divided the stimulus area into a 10 × 10 grid and tested one spot in each of the 100 squares by increasing the tension on the stimulus hair until either touch or pain was reported His results are shown in Table 7

The columns show the percentages of positive touch response at each stimulus strength for each subject The dashes indicate that the subject reported pain, or itching and spread of sensation, accompanied by increased latency of response The author interpreted such responses as indicating that the pain sensitive receptors had been stimulated

The results are difficult to interpret There seemed to be a diminution up to the sixth decade in the number of areas responding for all stimulus intensities This may indicate a diminution in number of receptors or of their sensitivity with age The subjects in the seventh and eighth decades showed a rise in number of areas responding Increase of stimulus strength showed a more rapid rise in number of areas responding in these subjects They also showed pain response at stimulus levels lower than those in the younger subjects The author suggested that these findings may be due to increased deformability of the skin in older subjects Unfortunately, the stimulus strengths were not carried to the point of pain threshold for all subjects, which would have allowed a comparison of the maximal number of touch sensitive areas for all subjects

Ronge (1943*b*) also studied histologic preparations of the volar skin of the distal segment of the index finger of nine autopsied subjects, ranging in age from 1 to 80 years He made sample counts of Meissner corpuscles and measured the area of the preparation to find concentration and total number His results are shown in Figure 17

jects of both sexes, ranging in age from 10 to 80 years Using their thermal stimulation technique on the foreheads of the subjects they found no age related changes in pain threshold Similar findings were reported by Birren and Schapiro (1950) who used the same technique However increases in pain perception threshold and pain reaction threshold were found by Chapman (1944) also with the same technique He used two hundred subjects, ranging in age from 10 to 85 years His sample was far more heterogeneous than that of Hardy *et al* and his group variability was far greater Since there were racial differences in thresholds it would have been necessary to know if there was a racial bias in the age distribution in order to evaluate age changes per se He found that the perception and reaction thresholds varied similarly

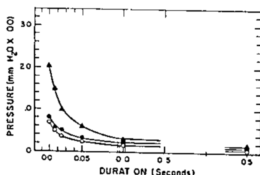


FIG 19—Pressure duration curves of corneal age ears

No age changes in sensitivity to pain (actually pain reaction threshold) were found by Wilder (1940) and by Sherman (1943), both of whom used a roughened grating inside a blood pressure cuff, measuring the pressure required to elicit pain reaction

Garibyan (1936) reported changes in the defense reactions of old dogs to needle pricks He found that the threshold for old dogs was 100 mm, while that for young dogs was 40 mm There were no age differences in the magnitude of response to 200 mm of pressure, although the nature of the responses differed The younger animals tended to have more local responses, while the older animals tended to have more generalized, gross responses

Ronge's (1943*a*) data, which were discussed earlier, indicated a lowering of pain threshold with age, which he attributed to the increased deformability of older skin

The clinical findings of decreased sensitivity to pain with age seem to be in partial disagreement with experimental findings Subject selection and test methods used may well be the factors producing these differences (see below)

Paraesthesiae—An experiment on age changes in ischemic and post ischemic paraesthesiae was reported by Poole (1956), who occluded circulation above the elbow for 10 minutes with a blood pressure cuff He tested 94 subjects, ranging in age from 12 to 84 years, dividing them into four groups of roughly 15 years' span each He found that the incidence of ischemic paraesthesia decreased from 100 per cent in the 12–30 year group to 72 per cent in the 31–45 and 46–60 year groups and then declined to 37 per cent in the 61 84 year group

The incidence of post ischemic paraesthesia was 100 per cent up to age 60 declining to 79 per cent in the 61–84 year group The average intensity and duration decreased with age Regression of duration on age was highly significant (p of less than 001) The incidence of post ischemic muscle twitching also decreased with age being 73, 75, 67 and 50 per cent from the youngest to the oldest group, respectively

These findings point to peripheral sensory changes, although the structural and functional correlates are certainly not clear

TEMPERATURE

The clinical findings of occasional diminution of sensitivity to temperature changes with age have been mentioned al

ready There seem to be no experimental data on this question The caloric method of testing for pain threshold would seem to be a good experimental method to be applied to this problem Hardy *et al* (1943) found that there is spatial summation of heat sensation but no such summation for pain This indicates that suprathreshold stimulation of an area containing one or a few pain sensitive receptors should suffice to elicit the subjective response A diminution of receptors for heat with age could be found by testing for spatial summation Since clinical testing for pain is usually carried out with a pin it may be that the difference in results between the caloric and the clinical methods lies in the size of the area stimulated since the area stimulated calorically is probably large enough to include at least one pain receptor

VIBRATION

The clinical and experimental findings of diminution of vibration sensitivity with age are in good agreement A quantitative study, using the cutting head of a phonograph record cutter, was reported by Cosh (1953) Testing 5–79 year old subjects, with approximately five subjects per decade, he found a small gradual rise in threshold at the fingertip and an accelerating rise in threshold at the great toe These results are shown in Figure 20 In this experiment he used a 5 millimeter stylus at 20 gm of pressure oscillating at 100 vibrations per second The ordinate of Figure 20 shows the average amplitude of vibration required to elicit sensation With somewhat less precise pressure control he found that the vibration threshold with age rose less in the sternum and more in the sacrum than in the great toe Similar findings were reported by Pearson (1928), Newman and Corbin (1936), Keighley (1946), and Rosenberg and Adams (1958)

Visceral Sensations

Other than the clinical statements, no data are available to indicate the prevalence or degree of reduced visceral sensations with age Electrical stimulation of tooth pulp may be a useful method to apply to this question

Kinesthesis

Laidlaw and Hamilton (1937) studied age changes in thresholds of apperception of passive movement in normal subjects There were forty subjects between 17 and

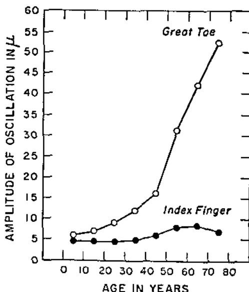


FIG 20 —Vibration thresholds of the index finger and great toe as a function of age. (After Cosh 1953)

35 years of age and twenty subjects between 50 and 85 years They measured the degree of movement required at various joints for the subject to report the correct direction of movement They found that more older subjects made errors in reporting direction of motion than younger subjects No sex differences were found They reported that older subjects required a greater degree of movement to reach subjective threshold in the hip and knee but showed little or no rise in threshold to motion of the joints of the upper extremities

In summary, somesthetic changes in aging do not seem to show a consistent pat

tern except for vibration sense There is a diminution in vibration sense with age, particularly in the lower extremities, which becomes marked after the fifth decade of life Kinesthesis and touch may show similar patterns Diminution of pain sensitivity with age has been both asserted and disputed There is no experimental evidence on changes in visceral and cutaneous temperature sensitivities, although decline of both with age has been reported clinically

VII General Considerations and Conclusions

The general picture of the course of sensory changes with aging is one of decline The specifics of this decline have been extensively enumerated their general effects must now be considered

The role and importance of sensory proccesses in relation to the functioning of the individual organism were discussed at the beginning of this chapter The reduction of efficiency found in sensory processes with aging reduces the quantity and quality of the information available to the organism This reduces the ability of the individual to interact with his environment Experience may compensate for the decrease in information input—the organism as a whole may respond more efficiently His ability to do so is discussed in other chapters of this book

The sensory decrement that occurs with age affects various modalities differently Thus some compensation between modalities is possible The general nature of the decrement can be categorized as consisting of neural and of non neural changes

The non neural changes are exemplified by reduction of pupillary aperture, increased opacity and yellowing of the lens, increased rigidity of the middle ear structures such as occurs in otosclerosis, etc These changes usually can be compensated for in part by increasing the stimulus intensities

Of far greater importance are the neural changes In general, these seem to consist of a reduction in nerve cell populations and hence of nerve-cell concentrations This reduces channel capacity Channel capacity consists of the maximum number of signals that can be transmitted during a given period of time When the number of elements in the channel are reduced, the same amount of information can be transmitted only by sending signals sequentially over the same elements, that is, an increase in stimulus duration becomes necessary If the amount of information to be transmitted can be handled by a given number of elements, this number of elements constitutes a larger proportion of the total

the relationship between the stimulus and the sensory organ response depends in part on the stimulus attenuation which may occur prior to receptor stimulation Such attenuation can be estimated by obtaining response curves as a function of stimulus intensities Stimulus attenuation will not change the slope of the curve, it will produce a parallel shift The change in slope that is found with aging is therefore indicative of a different kind of change, which occurs in addition to the change due to stimulus attenuation With the postulation that a constant number of receptor elements must fire in response to a brief stimulus to elicit an equivalent sensory response in young and old subjects, and that there is a reduction in receptor concentration with age, the obtained change in slope can readily be explained This viewpoint has been developed extensively in chapter iii

Alternative postulates are possible There may be a reduction of receptor sensitivity This could also produce a change in the Weber ratio, however, the total response range should not be diminished Functions which show optima with increasing stimulus intensity, such as critical flicker fusion or visual contrast sensitivity, could be used to test this assumption

Another possible postulate is that there

is a rise in synaptic thresholds This would also provide for a change in the Weber ratio Intracellular recording techniques could conceivably be used to test this assumption directly

The age curves of stimulus intensity versus stimulus duration shown in Figure 19 can be interpreted to indicate a reduction in the rate of signal transmission with age A stimulus which is supraliminal for all subjects will reach threshold sooner for younger than for older subjects This effect may well be multiplied at each transmission stage through the central nervous system, which would allow an explanation of the increased central component of reaction time with age (Weiss, 1956a)

The variable of age can be extremely useful in the elucidation of basic sensory processes because the sensory changes are clearly discernible in the functioning organism Beginning with the observed functional changes the discovery of related structural or physiological changes could indicate the bases of normal functions

It has long been disputed whether or not aging is a disease per se and whether the clinical conditions more common to the senium are physiological or pathological manifestations From an empirical viewpoint, these differences are largely semantic being based on certain differences in definitions It would appear that as the organism ages, its ability to interact with the environment changes it improves from birth to maturity and tends to decline thereafter The various factors within the organism which make it adaptable do not necessarily change *pari passu* A clinical disease state is said to exist when the organism apparently partly or totally succumbs to a noxious environmental force The increased susceptibilities to such forces that are found in advanced age may or may not be directly determinable, but these changes may conveniently be considered to be concomitants of the aging process Supportive and therapeutic attempts should be made in the aged to alter the environment, either external or internal or [illegible] reduce or [illegible] forces and [illegible] mechanisms [illegible]

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XVI

Perceptual Processes

HARRY W. BRAUN

I Introduction

The study of sensory and perceptual processes is one of the oldest divisions of the scientific analysis of behavior (Boring, 1942) Although our knowledge of many of these processes is extensive, comparatively little is known about their relationships to aging Through the senses we maintain contact with the environment. And through these senses various aspects of the environment seek to control behavior—educational, religious, business, industrial, political, artistic, and advertising institutions, to mention a few To the extent that these senses are impaired or somehow modified, our ability to interpret and adjust to the environment may be affected Impairment or other modification of the senses is known to occur with aging, and the effects of these changes on perceptual behavior will be described in this chapter

Space does not permit the detailed description of the various perceptual phenomena as they are understood and known in their own right and without reference to age Nor will the psychophysical methods and other research techniques be presented The reader may refresh his knowledge of these topics with the aid of standard texts (e g, Geldard, 1953) The previous chapter has discussed the physical changes in the sense organs as they may occur with age and also changes in the processes of converting physical stimuli into sensations Emphasis in the present chapter is on the relationship between age and perception, the processes of attaching meaning to stimuli In practice it is impossible to discuss age changes in perception without some reference to sensory thresholds, and to this extent there is some necessary overlap of the content of this chapter with the previous one.

II Definitions

Although the definitions of the word "perception" are many, they may be grouped into several classes, as has been done by Verplanck (1957) First, "perception" is a general term for the control of behavior by either simple or complex stimuli, as such control is inferred from the behavior When the stimuli and/or responses are relatively simple (i e, quantitative), it is common to speak of "sensory processes" or "sensation" When they are complex (i e, relatively not quantitative), we speak of "perceptual processes" or "perception" As Graham has demonstrated, "the terms 'sensation' and 'perception' probably do not refer to two different operationally specifiable concepts" (1958, p 76) This type of definition is empirical and stands in sharp contrast to the second class According to the second class, perception is a "hypothetical internal event of unspecified nature controlled largely by external stimulation (but sometimes also by state variables such as habit and drive)" (Verplanck, 1957, p 23) To these state variables we might add age Verplanck suggests even a third class when he states that "such events are often

treated as though they were the true controllers of behavior' (*ibid*)

Research on age differences in perception or sensation may be classified in terms of these definitions First, there are relatively empirical studies in which functional relationships are sought between the responses of subjects of different ages and various complex stimuli for example, a light source which is used to determine sensitivity to light Research of this type is often carried out to test the validity of certain commonly held beliefs for example, that age differences exist in susceptibility to illusions

A second group of studies may be identified in which perception is regarded as an intervening variable between stimuli and responses This inferred construct is then related to an experimental variable, such as stimulus or task complexity, and the relationship between age and perception is then assessed (Birren and Botwinick, 1955) This type of limited theory construction is not unlike in its formal aspects that of Hull (1943) and Spence (1956) in the field of learning

Finally, a third approach regards perception as an intervening variable which is in some usually unspecified way related to another such variable, for example, cognitive functioning Age differences in response to complex stimuli are ultimately ascribed to some characteristic of the controlling state variable, for example, cognitive functioning This orientation reflects the influence of the "new look" in perception in which its attitudinal or motivational determinants are sought

In this review of research on age differences in perception, studies will be grouped, in general, on the basis of the stimulus variable that is common to them Assignment of a given study to one of the above classifications is comparatively easy

III Visual Perception

Acuity

Before one can consider age changes in the recognition of objects, there is the prior issue of age changes in the resolving power of the visual system Visual acuity refers to the smallest object which can be discriminated at a given distance in a given illumination or to the smallest separation between two objects that can be detected The previous chapter has discussed in detail changes in acuity which have had a long history of study beginning with Galton in 1884 Ruger and Stoessiger (1927) found a correlation of — 51 between age and acuity An initial fact in the study of perception is the existence of a widespread diminution of acuity with age (Collins and Britten, 1924)

To some extent the changes in acuity appear to be related to such factors as retinal changes and reduction of pupil size (Birren and Bick, 1948, Birren, Casperson, and Botwinick, 1950) Such findings would suggest a relationship between level of illumination, visual acuity, and age, and this relationship was studied by Weston (1948) Weston presented twelve subjects ranging in age from 24 to 48 years with sheets of paper which contained Landolt rings (see also chap xv, pp 514–16) The position of the gap varied from ring to ring, eight positions being used The subjects were asked to indicate all rings with gaps in a particular position by canceling them with a pencil stroke Three sizes of rings were used, and the intermediate size corresponded to the size of newspaper type Each task was performed at six levels of illumination Performance declined as age advanced, and the decline was sharper under conditions of low illumination than high illumination When illumination was changed from the lowest to the highest values, the performance of the young group improved by 18 per cent, while that of the oldest subjects increased fourfold At higher levels of illumination the performance of older subjects drew closer to that of the younger, but at no level did the acuity of the older equal that of the younger Weston's subjects were timed, and he was able to separate motor (cancellation) time from visual discrimination time After controlling for cancella

tion time, it was found that discrimination time increased greatly with age Weston attributes the decline in performance with age to a slowness in the perceptual process (see Sec XI) The importance of timed tests in the study of age differences in visual acuity is suggested by Weston when he notes that previous research using untimed tests (e g , the Snellen test) does not show as marked decline in acuity with age In a study by Gregory and Cane (1955), a spot of light was flashed for about 0 057 second on an illuminated background, and subjects had to report when the spot was just seen The intensity of both the spot and the background could be varied In a second experiment a steady spot of light was presented, and subjects adjusted it so that it was just visibly brighter than the background In both cases the ratio of the difference threshold to the intensity of the background illumination was greater in older subjects than in younger subjects This finding that Weber's ratio (dI/I) increases with age also was reported by Weston (1948), who used a different measure of acuity, and by Coppinger (1955) in his study (described below) of the relationship between the threshold of critical flicker fusion (CFF) and of brightness These findings are incorporated in an information theory approach to behavioral changes as

[illegible]
in "signal level' and a rise in 'noise level" in the older nervous system

LIGHT THRESHOLD

Recognition of objects in very low illumination should be affected by age because of the demonstrated age change in the light threshold after dark adaptation (Birren, Bick, and Fox, 1948, Birren and Shock, 1950) Changes in the light threshold with age may also be expected to be a large factor in the constriction of peripheral vision or reduced visual field (Mann and Sharpley, 1947) This reduction is apparently less marked in light conditions (Ferree *et al*, 1930)

CRITICAL FUSION FREQUENCY

At some frequency a flickering light will be seen as steady, this fusion point (CFF) has been studied in aging and in neuropathology Because of the change in the light threshold noted above, it should be expected that there will be an age change in CFF, but there may be other components as well which might be more "perceptual" in nature The data of the previous chapter indicate that the fact of a change in CFF with age leaves little to contest The data of Misiak (1951) are perhaps representative

It is an established fact that CFF increases with the intensity of the light phase, but Coppinger (1955) has shown that, when the brightness of the stimulus was increased, the fusion threshold was higher in young subjects than in the elderly This finding is consistent with the fact that the minimum light threshold is higher in the elderly The subjects were 120 men aged 20 through 79 years Binocular foveal CFF was measured at three levels of stimulus brightness 0 09 millilambert (level 1), 0 54 millilambert (level 2), and 1 74 millilambert (level 3) When stimulus brightness was elevated from level 1 to level 3, the threshold of the young subjects was raised from 18 00 to 40 75 cycles per second On the other hand, at the same increase in stimulus intensity, the threshold of the elderly subjects rose from 12 72 to 31 64 cps It is apparent that changes in CFF with age were not related to a difference in initial or minimal threshold Thus the elderly showed a greater relative increase and a smaller absolute increase in threshold as brightness was increased This decreased sensitivity can be regarded in terms of Weber s law, which states that the fraction by which a stimulus must be increased or decreased for a difference to be just noticeable is constant, regardless of the magnitude or intensity of the stimulus The data of Coppinger (1955) as well as those of Weston (1948) suggest that Weber's ratio (dI/I) increases with age

Coppinger's data are also in agreement with those of Misiak in that the relation-

ship between CFF and age is linear and negative, but Coppinger did not find inter individual variability to increase with age Greater variability, however, was associated with increased brightness for all age groups

The light dark ratio, together with brightness, was varied by Fisher (1955), but under all conditions the fusion threshold was lower in older subjects Light proportion in the cycle was varied in eight steps from 0 02 to 0 98 Apparently, the recovery phase of the photosensory process of the retina is not modified by age, and lowered CFF is explained by known changes in the visual system

A significant relationship between intelligence and CFF, when age was controlled, was secured by Colgan (1954) He suggests control over intelligence in future studies and speculates that both CFF and intelligence depend upon the same neural functions which are impaired with age

COLOR VISION

Until recently research on color vision in the later years has been meager, and the results have been inconsistent Tiffin and Kuhn (1942) reported that 65 per cent of workers over age 55 failed in red green color discrimination and that 26 per cent of those in their twenties failed on the same discrimination This latter finding is at variance with the usual results secured with other color vision tests Because of this fact, and because of the doubtful validity and reliability of the test (which contained only four color plates), additional research has been carried out Thus Boice *et al* (1948) reported no deterioration in color vision in 236 university faculty men aged 20–59 years with the Ishihara and American Optical Company tests Chapanis (1950) reported essentially the same lack of relationship in a study of the color vision of 574 subjects aged 7–77 years He also found a slight positive relationship between color vision test scores and visual acuity, but he discounted this as lacking practical significance, since the correlations were so low On the other hand, Kleemeier (1952) found a correlation of 675 between far distance binocular acuity and color vision on the Ortho-Rater and suggests that visual acuity must be controlled in attempts to determine the relationship between color vision and age

Besides tests such as the Ishihara, matching techniques have been used in the study of color vision and age Smith (1943) required 199 subjects aged 5–78 years to match varied with standard patches on the basis of hue, saturation, and brightness For all three matchings, curvilinear relationships similar to those for visual acuity were reported Unfortunately, color blind individuals did at least as well as color normal subjects, which suggests that the matchings were made on a basis other than color, perhaps texture

An extensive study of the color vision and age relationship with a matching test has recently been made by Gilbert (1957) She administered the Color Aptitude Test to 355 subjects (160 male and 195 female) between the ages of 10 and 93 years. Separate color and total test scores rise to the twenties and then steadily decline At all ages discrimination of blue and green shades was more difficult than of red and yellow Ability to match blue and green also declined more rapidly with age Gilbert (1957) and Chapanis (1950) ascribe the more rapid decline in ability to match blue to the filtering effect of the progressive yellowing of the lens with age Gilbert's data also suggest a relationship between acuity and color vision or between both and some common factor that is operating as the visual system ages The findings of Gilbert possess implications for those of the elderly who work with colors, but she also states that we do not know the effect of practice on maintenance of efficiency in color matching

PERCEPTION OF PATTERN AND FORM

Brian and Goodenough (1929) showed that, in adulthood, form rather than color

influences the perception of an object Subjects who ranged in age from below 2 years to adulthood were presented with two objects differing in both form and color They were then shown a third object which matched one of the objects in form and the other in color and asked to select that one of the two objects which matched the third Children under 3 years of age matched on the basis of form, those from 3 to 6 matched according to color Thereafter form influenced selection

Another aspect of form perception, preference for rectangular proportions, has been studied as a function of age Thompson (1946) determined preferences of rectangles of constant length but different proportions by preschool children third graders sixth graders, and college students As age of the children increased similarity to the adult standard increased Nienstedt and Ross (1951) extended this study by using a hundred college students and fifty subjects between the ages of 61 and 91 years The older group showed a preference for the rectangles with greater width length ratios—a preference which was also shown by Thompson's sixth graders The authors concede that the significance of this finding is not clear to them

PERPENDICULARITY BISECTION, TRISECTION

Data on these variables were obtained in 1884 by Galton, who tested over seven thousand visitors to his first anthropometric laboratory at the health exhibition in London Among the seventeen traits which he measured were three which he named "sense of perpendicularity" "error of bisection," and "error of trisection ' Error in judgment of perpendicularity was measured in degrees, while the other two errors were determined in percentage of the length bisected or trisected From the tabulation of Galton's observations by Ruger and Stoessiger (1927) Miles (1935) computed correlation coefficients between the various errors and age in the range 25–81 years These values were error in perpendicularity, $N = 3815$, $r = +.058$ ($\pm$.011), error of bisection, $N = 3829$, $r = +.071$ ($\pm$.011), and error of trisection, $N = 3892$, $r = .033$ ($\pm$.011)

VISUAL PERCEPTUAL SPAN

Price (1931) measured visual perceptual span in subjects aged 50–90 years Cards which contained either letters, numbers, colors, line figures sentences, or deleted words were presented for 0 1 second, and subjects recorded what had been seen The correlation between age and total scores was − .56 for men and − .43 for women Individual differences tended to increase with age It would appear that these results can easily be related to the discussion of perceptual speed and difficulty presented below

IV Auditory Perception

Our knowledge of anatomical and physiological changes in the ear with aging was discussed in the previous chapter The national health survey conducted by the United States Public Health Service in 1935–36 and reported by Beasley (1940) provides data to support the common belief that the incidence of deafness increases with age Data in that study were gathered from a sample drawn from more than two million people in various parts of the country and house-to-house canvasses were made The deafness associated with increasing age is accounted for in great part by increasing inability to hear tones of high pitch (presbycusis) This was shown in two studies by Bunch (1921, 1929), who conducted audiometric tests in 821 subjects aged 20–60 years

In a similar study, but using a soundproof room, Kelley (1939) extended the age range to 86 years and found no significant loss for tones below 512 cycles from 60 to 86 years Kelley's 50–70 year old group did not show as great a loss as Bunch's for tones of 1024 and 2048 cycles

The decibel values of the two studies for tones of 4096 and 8192 cycles are comparable

PERCEPTION OF MUSIC AND SPEECH

Kelley (1939) has also provided information on the effect of high tone deafness in older subjects on the perception of music vowels, and consonants Subjects were first asked to decide whether a difference in quality existed between a natural violin tone and a second tone of the same pitch from which various high frequencies had been filtered In subjects over 60 who had high tone deafness the removal of frequencies over 4000 cycles did not result in judgments of "different" whereas in subjects with normal hearing the difference between two tones was marked

Subjects were also asked to identify vowels and consonants in monosyllabic words which were transmitted over an amplifying system at levels of intensity ranging from 40 to 10 decibels above the average normal hearing threshold At all levels of intensity subjects with high tone deafness were deficient in recognition of consonants In perception of vowels these subjects were handicapped only at the 10 decibel intensity level, where they identified only half of the vowels that normal subjects could recognize

V Gustatory and Olfactory Perception

TASTE PREFERENCES

The limited evidence of age changes in taste thresholds was discussed in the previous chapter An increase in preference for tart taste and a decrease in sweet choices has been found in elderly subjects aged 50–68 In this study Laird and Breen (1939) used pineapple juice which varied through five equally perceptible intervals of sweetness from tart to sweet The method of paired comparisons was used to establish preferences in 120 subjects ranging in age from 12 to 68 years Below age 50, sweet preferences were predominant The change in preference was ascribed to atrophy of taste buds in the anterior part of the tongue which are most sensitive to sweet

AFFECTIVE REACTION TO ODORS

Kneip *et al* (1931) found no differences in likes and dislikes for fourteen odors in two hundred subjects between the ages of 7 and 24 years

Taste and smell have been referred to as the poor relations" of the family of senses Our knowledge of these sensory phenomena is not extensive, not only in and of themselves, but also in their relationship to age.

VI Cutaneous Perception

The cutaneous senses include pressure, pain, cold, and warmth, these are the four primary skin experiences Our knowledge of the relationship between aging and cutaneous sensitivity is sparse

WEIGHT DISCRIMINATION

The discrimination of lifted weights by elderly (58–85 years old) and young adults (18–32 years old) was studied by Landahl and Birren (1959) The method of constant stimulus differences was used The standard weight was 100 grams, while the comparison stimuli weighed 100, 105, 110, or 115 grams Subjects were given ten different series of unspecified length Among the variables or procedures which distinguished the series were simultaneous right and left hand discrimination, successive presentations of stimuli to same hand, 2 or 10 seconds' delay between first and second weights in a pair, normal judgment time and fast judgment Response time was recorded in some of the procedures In the simultaneous discrimination task the relative performance of elderly to young in correct judgments was about 70 per cent for normal speed and 60 per cent under the fast judgment condition On the successive

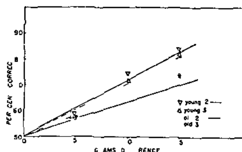
discrimination task under these same speed conditions the young were only slightly superior to the elderly Percentage correct responses in simultaneous discrimination as a function of the difference in the two lifted weights are shown in F gure 1 An increase in delay from 2 to 10 seconds between the first and second stimulus did not affect performance in either age group on both simultaneous and successive discriminat ons In both groups age and successful discrimination were significantly correlated under both judgment time conditions In all the series the response time of the older subjects was on the average 0 5 second slower than that of the young In neither group was response time related to difficulty of discrimination defined in terms of weight differences in the d scriminanda This finding stands in contrast to other data which are presented later in this chapter which show that response (reaction) time increases as the difficulty of various perceptual tasks increases

VIBRATORY SENSITIVITY

Pressure sensitivity has intensitive spatial and temporal aspects The temporal feature is most apparent in the case of vibration which has been referred to as pressure in movement Several studies of vibratory sensitivity and age have been carried out With the aid of an instrument *which produced a vibration of constant fre*

vibration could be just felt when the instrument was placed over the patellae and medial malleoli of 125 subjects ranging in age from the second to the ninth decade The threshold increased gradually with age until the fifth decade when the increase was more rapid Data on vibratory sensitivity at 76 different points on the body have been obta ned by Laidlaw and Hamilton (1937) With the aid of a pallesthesiometer thresholds were determined on 40 young adults aged 22 28 years and 20 old adults whose age ranged from 50 to 85 years In general thresholds were higher in the old group and this decreased sensitivity was greater in the trunk and lower extremities of the body than in the other parts On the other hand Pearson (1928) reports that vibratory perception is most efficient in adolescence it then decreases slowly until the fifth decade and more rapidly thereafter In his review of these studies Birren comments as follows

> Although vibratory sensitivity declines s gnificantly in later life the interpretation of this impairment is still not settled With continued improvement in apparatus and the increased scope of subjects measured under a variety of conditions the usefulness of vibratory thresholds as an index to important bodily functions may be appraised If wider ranges of frequencies are used in experimental investigat ons a different al effect of aging upon higher frequenc es may be found s milar to that observed in *audition* [1947 p 268]



F G 1 Percentage of correct responses as a function of the difference n the two lifted weights Data are given for simultaneous discriminat on two category (r ght or left) three category (right left or same) Lines are plotted through we ghted average (After Landahl and B rren 1959)

DOUBLE SIMULTANEOUS TACTUAL STIMULATION

An interesting response to stimulation of the face and hand has been reported by Bender *et al* (1951) After the subject closed his eyes the cheek and any part of the ipsilateral and contralateral hand were simultaneously touched or stroked with the experimenter s fingers Subjects were asked

to report the presence of either one or two stimulations or sensations Trials were repeated until the subjects could report double stimulation On the first few trials in the series both children and adults reported only one sensation that of facial stimulation and this phenomenon was termed face dominance ' On subsequent trials up to ten or twelve both children aged 3 6 years and elderly adults aged 61–96 years continued to report a very high percentage of face-dominant responses (Bender and Green 1952) Older children and young and mature adults reported double stimulation after the first few trials The phenomenon of single (facial) stimulation was observed only if two non homologous areas (face and hand) were involved Two sensations were reported correctly when two homologous areas were stimulated either both cheeks or both hands Similar results were obtained with pin prick stimulation of the face and hands Patients with diffuse brain damage gave a frequency of face-dominant responses comparable to that of children and old normal adults This is understandable since in young children the central nervous system is relatively immature while in old adults various neural degenerative changes have taken place or are in progress

TEMPERATURE SENSITIVITY

Evidence that the elderly are less able to maintain their normal body temperature when exposed to cold has been provided by Krag and Kountz (1952) Thirteen subjects aged 57–91 years and six young persons aged 23–36 years lay unclothed in a cabinet in which the air temperature was 5°–15° C for from 45 to 120 minutes None of the elderly had considerable discomfort and none complained of chilliness later in the day When exposed to heat (38°–45° C) for from 60 to 90 minutes the temperature of the elderly increased (Krag and Kountz 1952) Little change was recorded in body temperature of young subjects under both conditions

PAIN SENSITIVITY

The observation that individuals differ markedly in sensitivity to pain suggests that this phenomenon may be related in part at least, to age The data reviewed in the previous chapter (e g , Chapman and Jones 1944) suggest there may be changes with age in the pain threshold and in reactivity to pain, but the data are insufficient to discern such factors as the role of threshold and attitude toward pain in differential age reactivity to pain

VII Kinesthetic Perception

PERCEPTION OF DIRECTION OF MOVEMENT

Age changes in certain motor skills may depend in part upon the perception of movement of body parts This variable was studied by Laidlaw and Hamilton (1937) in a young group aged 17–35 years and an elderly group aged 50–85 years Limbs were placed on hinged platforms which could be cranked up or down, and subjects were to report the direction of movement as soon as they could detect it The threshold measure was the angular position of the limb which existed when the direction of movement was perceived The thresholds of the older group were larger and more variable and they made approximately three times as many errors in identifying the correct direction of movement

PERCEPTION OF ILLUSIONS

Although it is generally believed that age differences exist in susceptibility to geometrical illusions research on this relationship has not been characterized by the systematic manipulation of the age variable In the only extensive study, Hartmann and Triche (1933) presented eight illusions to 247 subjects Seventy subjects were in Grades I and II 102 in Grades V and VI and 75 were college juniors Among the illusions employed were the Sander parallelogram the Muller Lyer illusion Jastrow s

figure, and Koffka's squares Each illusion was drawn on cardboard and presented to the subjects for 10 seconds The lines or areas to be judged were labeled "A" or "B," and the subject was required to write on a sheet of paper the corresponding letter for the line or area which appeared longer or larger Children were significantly more susceptible to the standard Muller-Lyer illusions, while adults were more susceptible to a modified Muller Lyer illusion Age differences for the other figures were not significant Although the authors state that more pronounced age differences might have been obtained if nursery or preschool children had been tested research with geometrical illusions also seems desirable in which mature and older subjects are employed

The prediction of Hartmann and Triche was not confirmed when Cramausel (1927) failed to note the Muller Lyer effect in 82 children 4–7 years of age, but he did find it in subsequent years Since the Muller

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decreased with age

The phantom limb phenomenon is an interesting and striking illusion and Jalavisto (1950) has shown how adaptation to this illusion is related to age Her subjects were 173 arm amputees (veterans of Finnish wars) aged 17–45 years Subjects were asked to describe the phantom sensation and also to describe the sensation present when they had to move the stump of the arm so that the phantom, if unchanged, would occupy some place within a wall or a table These tests were carried out from within 3 weeks to over 3 years after amputation, but the majority of the subjects were examined from 8 to 10 months after amputation At examination the phantom was classified into one of the following categories (*a*) not present, (*b*) located within the stump, (*c*) disappears or shuns the obstacle when the stump is placed near a wall, (*d*) occupies a place within the wall, and (*e*) descriptions vague The first three groups were regarded as representative of an adaptive reaction, while the other two groups were considered indicative of a fixed, rigid reaction Reactions of adaptation were more frequent (62 per cent) in a young group aged 17–24 years than in an older group (38 per cent) aged 25–45 years This age difference is greater in examinations made within 6 months after amputation than after this time, which indicates a more rapid rate of adaptation to this illusion in the young

VIII Perception of Ambiguous Stimuli

KINEPHANTOM

Although Miles (1934) regarded his study of age differences in response to the kinephantom as being concerned with imagination and judgment, its inclusion in this chapter seems to be indicated The stimulus was a silhouette formed by projecting the shadow of a two-bladed fan at one revolution per second in a plane at right angles to a translucent screen This stimulus yielded several interpretations, such as stretching, crossing, oscillating, etc Each subject was asked to report verbally or by gestures what was seen happening on the screen during the 3 minutes of stimulation The number and kinds of movements which the subject reported were recorded Miles tested 616 males and 587 females ranging in age from 25 to 89 years The results failed to show age differences either in the number of kinephantoms reported or in the number of phases or changes in the kinephantoms during the period of stimulation For the youngest group (25–29 years) the mean number of kinephantoms was 2 42, and the mean number of phases was 24 0 For the oldest group (70–89 years) these mean values were 2 22 and 23 9, respectively

PERCEPTION OF INCOMPLETE FIGURES

Verville and Cameron (1946) investigated age differences in the identification of ten incomplete pictures of common objects such as a steamship, a piano, and a frog The young group of subjects ($N = 100$) were college students aged 16–23 years The elderly group ($N = 30$) were profes

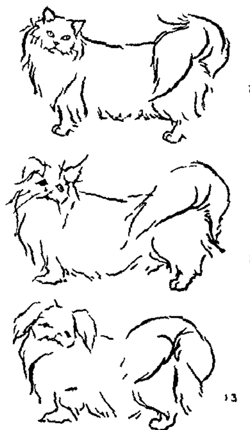


FIG 2.—Cards 1 7 and 13 of the Cat Dog Series. (After Korchin and Basowitz 1956)

sional people aged 35–56 Each picture was projected on a screen, and records were made of the subjects' responses and their time of occurrence If the picture was not correctly identified within 5 minutes a verbal prompt was given by the experimenter ("This is an animal" for frog), and the picture was shown for 2 additional minutes Correct identifications were made signif-icantly more rapidly by the younger group Within the elderly group, men were superior to women The authors state that several factors may have contributed to the poorer performance of the older group One of these was apprehension resulting from the suspicion that the test was one of intel liger the serial nature of the prec slow response on the next picture

Another study with incomplete figures was made by Street (1931), who used 754 grade school and high school pupils The subjects were asked to identify each of after they had inspected did not measure speed of correct identification

A different approach to the study of the perception of ambiguous stimuli has been reported by Korchin and Basowitz (1956) The test stimuli consisted of thirteen line drawings The first drawing in the series was clearly a cat, and the succeeding drawings were gradually modified until the last was unmistakably a dog Figure 2 contains the first seventh and thirteenth drawings (i e the clearest cat the most ambiguous picture, and the clearest dog) These stimuli were projected on a screen, and the subjects were told to identify each drawing as a dog or as a cat They were told that they had unlimited time and that the task was not a test The younger group of subjects ($N = 24$) ranged in age from 22 to 33 years while the age range of the older group ($N = 36$) was 65 to over 85 years The older group was significantly slower in the time required to make a decision or identification The younger subjects shifted from the cat response to the dog response near the middle of the series and generally maintained the dog response to the end of the series The point of shift from cat to dog was significantly later in the elderly group, and more vacillation after the first dog response was observed Decision (reaction) time patterns for early and middle

stimuli were not appreciably different in the old group, indicating that reaction time was not related to stimulus ambiguity

A systematic investigation of the relation ship between age and form recognition has been reported by Crook and his collabora tors (1958) The subjects were 176 males with normal vision, of slightly better than average education, and ranged in age from the middle teens to the late fifties The test materials were "Gottschaldt" forms (sim ple geometric figures imbedded in more complex designs), "Street" forms (incom plete figures), silhouettes of familiar forms and irregular forms With the first three materials, the subjects' task was that of identification In the case of an irregular form, it and a slightly modified version of it were presented, and the subject was asked whether they were identical The various materials were presented on a screen, and the following aspects of the viewing situation were varied exposure time, luminance, contrast, and an overlay of visual noise (masking) With optimum viewing conditions and long exposure time little or no effect of age was found in form perception (i e, form discrimination rec- ognition, or identification) With shorter exposures, decreasing luminance decreas ing contrast, and the addition of an over lay of visual noise, decreased performance with age was found and this became more marked as the conditions became more se vere Decrease in luminance produces changes in performance apparently corre- lated with physiological changes in the vis ual mechanism with age It is apparent that, as the difficulty of the perceptual task increased, age differences in performance were observed On the basis of other re- search described later in this chapter, it would be expected that response or reac tion time would increase with age and per ceptual difficulty However, clear-cut data are not presented on this relationship

RORSCHACH TEST

The Rorschach test is a projective tech nique which is used to appraise certain as pects of personality The literature on the relationships between Rorschach protocols and their implications for personality or ganization in different age groups is sur- veyed elsewhere However, the Rorschach is basically a set of ambiguous stimuli to which perceptual responses are made Ches row *et al* (1949) have reported that these responses are slower, fewer, and stereo typed in a group of subjects ranging in age *from 64 to 83 years On the other hand* Caldwell (1954) failed to obtain a signif icant correlation between age and the total number of responses to these stimuli in a group aged 61–92 years In fact, she ob tained only two significant correlations be tween age and usual Rorschach response categories, human movement responses and good original (O +) responses both of which were positive Caldwell also showed that the quality of form perception (F + responses in which the perceived form cor- responds closely to the actual shape of the stimulus blot) bore a positive significant relationship to various intelligence meas ures The correlations between these meas- ures and the percentage of response deter- mined by form alone were negative, while those with the number of different deter minants of response were positive Thus Caldwell points up the importance of intel ligence or intellectual functioning in elder ly subjects in perceptual responses to am biguous stimuli

IX PERCEPTION OF CLOSURE

GESTALT COMPLETION TEST

In the experimental study of the percep tion of closure, stimuli are more structured and less ambiguous than those similar to Rorschach blots Tests of perceptual clo sure may require subjects either to organ ize (achieve) or to resist closure Basowitz and Korchin (1957) compared a young and an old group, mean ages 26 8 and 78 1 years, and equated for intelligence, on both types of closure The capacity to organize was investigated with the Gestalt Com-

pletion Test, in which subjects were instructed to identify, during 10 minutes, seventy two fragmented drawings of distinct persons, objects, or situations after they had been shown some examples No difference was found in the number of drawings examined or attempted by the two age groups The younger group made significantly more correct identifications and significantly fewer incorrect identifications According to these authors the 'wrong responses of the older subjects showed signs of perseveration fixations on details concretization vagueness and poor articulation of form Older subjects also failed to respond significantly more often than the younger Cautiousness or impotence in the closure function were hypothesized to account for this

CONCEALED FIGURES

Basowitz and Korchin (1957) employed the Concealed Figures Test with the same groups to study resistance to closure Subjects were presented for 10 minutes with forty nine rows of figures each row of which contained on the left a simple geometric design followed by four more complex designs in at least one of which the simple design was imbedded Subjects were instructed to identify each of the complex designs which contained the simple figure 'Since the complex figure has good Gestalt its properties of closure must be resisted as S searches for the smaller figure potentially hidden therein (Basowitz and Korchin 1957, p 94) The younger group completed significantly more items than the older group, and with correction for this fact the right wrong performance of the younger group was significantly superior Failures to respond did not occur on this test, a fact which the authors attributed to the instructions The results of this study as well as those with the Gestalt Completion Test were viewed "as reflecting the overly loose or overly rigid cognitive functioning of the aged' (Basowitz and Korchin, 1957, p 96)

A test of closure was used by Glanzer and Glaser (1959) in a battery designed to measure age related changes in skills required for performance of air crew officers In this Object Identification Test the subject was required to identify relevant objects (plane, tower) and "nonsense' or geometric objects under two degrees of masking 75 per cent and 90 per cent Some of the objects were rotated 90° under the mask Each subject was provided with exact pictures of each object, and a total of 84 stimuli were presented during 9 minutes The test was given to 544 Air National Guard officers and commercial air line pilots between the ages of 20 and 50 The correlation of Object Identification Test [illegible] dicate [illegible]

In [illegible] perceptual closure, Wallace (1956) exposed only a small portion of a stimulus object initially and then gradually revealed more of it until subjects could identify it Her sixteen young subjects were under 30 years of age and her sixteen older subjects were over 60 Four stimuli of each of the following kinds were presented outlines of geometric figures (triangle), silhouettes of simple figures (star), meaningful silhouettes (child), and more complex pictures (policeman leading two children across the street) In one experiment each picture was shown through a horizontal slit 0 1 inch wide If the picture was not identified the width of the slot was increased to 0 2 inch and so on to 0 5 inch No age differences were found in correct identifications of geometric figures and meaningful silhouettes The aged group was significantly less successful with silhouettes of simple figures and even more inferior with the complex pictures In a second experiment each picture was shown [illegible] ther 0 1 inch [illegible]

both conditions the two groups were [illegible] significantly different Wallace concluded that "the greater difficulty of older subjects

with complex material appeared to be due mainly to the greater amount of temporal integration required with such material (1956, p 283)

FACTOR ANALYSIS OF THE WECHSLER BELLEVUE SCALE

Closure was one of the factors extracted by Birren (1952) in his analysis of the scores of elderly persons (60–74 years) on the Wechsler Bellevue Scale The so-called performance tests of the scale were high in this factor and included picture arrangement, picture completion and object assembly Of some interest is the additional finding that a group of thirty one senile patients showed their greatest relative loss in this factor

X TIME PERCEPTION

That the older person would underestimate objective time is an attractive hypothesis which was tested by Feifel (1957) The mean age of his older group ($N = 40$) was 67.0 years and that of his younger group ($N = 39$) 24 0 years Subjects were asked to delimit or produce intervals of 30, 60, 180, and 300 seconds Although both groups underestimated all intervals, the degree of underestimation in the older group was significantly greater

Earlier, Gilbland and Humphreys (1943) compared fifth graders ($N = 48$) and college students ($N = 48$) in their ability to estimate, produce, and reproduce intervals of time ranging from 9 to 180 seconds The young adults were superior to the children at all intervals by 15–18 per cent In both groups very short intervals tended to be overestimated while longer intervals were underestimated, a result which is consistent with Feifel s Methods of judgment did not seem to be a source of variation.

XI PERCEPTUAL SPEED

Speed of perception has emerged as an important construct to account for, at least in part, the characteristic slow responses of elderly individuals Slowness or difficulty in perceiving the stimulus is assumed to constitute a large portion of the increased response time that is observed with aging Furthermore, speed of perception is considered an important feature of the thought processes or of mental activity, and thus this age change (i e, slowness of response) is assigned a central rather than a peripheral localization In the experimental investigation of age differences in perceptual speed, task or discrimination difficulty is usually the manipulated variable, and response latency is the dependent variable Several experiments which are based on this rationale have been reported by Birren and his associates.

SPEED AND ACCURACY OF ADDITION

Birren and Botwinick (1951) investigated the relationship between age and rate of addition as a function of difficulty as measured by problem length. Subjects were 193 high school students in the age range of 16–20 years and 50 normal adults aged 60–69 years They were required to add as quickly as possible columns of digits that varied in length from 2 to 10, 15, and 25 digits and to write their answers Speed of writing was also measured by having subjects write digits as quickly as they could in either 40 seconds or 2 minutes (1951) Young subjects were superior in the rate of total and correct addition and showed less decline of correct addition with increased problem length Pertinent to the present discussion of perceptual speed was the finding that speed of writing correlated more closely with rate of addition for elderly subjects than for the high school students In both groups the correlations decreased as a function of problem length until stable values were reached at problems of five digits or longer (Fig 3) Commenting on these results, Birren writes

> It appears, then, that writing speed did not disproportionately impair the output of the elderly These results indicate that slowing in

speed of doing addition problems goes beyond simple considerations of the effector or output processes and perhaps is related to a change in a general speed factor underlying many perceptual processes [1955 pp 238–39]

In an extension of this study, Birren *et al* (1954) considered the relationship of simple addition to the length of the series to be added time and probability of success Results were obtained on 413 subjects in the age range 16–90 years The elderly subjects were slower for all lengths of problems and were less accurate as length of problems increased The authors interpret this loss of speed in the elderly as 'a phenomenon basic to mental events and one intimately involved in aging of the nervous system" (p 160)

JUDGMENT OF LENGTH OF LINES

Another approach to the study of perceptual speed as a function of task difficulty involved judgments of differences of length in tachistoscopically presented lines In this experiment Birren and Botwinick (1955) reasoned that, if elderly subjects have a perceptual deficit, their response times should become relatively faster than those of young subjects as stimulus judgments become easier The young group ($N = 30$) ranged in age from 19 to 36 years, and the age range of the old group ($N = 43$) was 61–91 years Two lines were presented simultaneously for sufficient time (never more than 2 seconds) for the subject to indicate by vocal response the shorter line A series of line pairs was employed

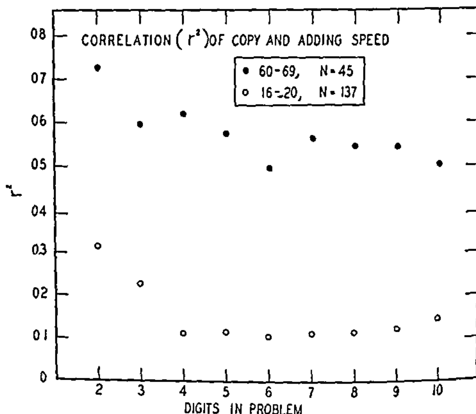


FIG 3 —Correlation (r^2) between speed of writing digits and the rate of addition for problems of different lengths. Values are based on 137 sen or high school students and on 45 normal elderly subjects. (After Birren and Botwinick, 1951)

which varied in length from 1 to 50 per cent In both groups, response time was slower with increased line length and reached an asymptotic value at approximately a line length difference of 15 per cent (Fig 4) The response time of the elderly group was significantly slower with all levels of stimulus difficulty and became relatively more slow as differences in the lines decreased The authors regard perceptual difficulty as a factor in producing exposure, the study was replicated with 0 15 second stimulus exposure At this latter exposure time speed of response was quicker in both groups than under the 2 second condition, and the largest reduction was obtained for the difficult discriminations of the elderly group The older group was less accurate, but this age difference was unrelated to stimulus difficulty or exposure duration It thus seems inappropriate to regard reduced stimulus exposure

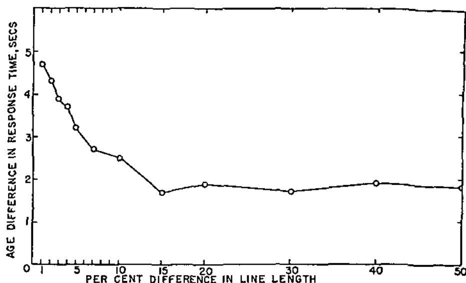


Fig 4 —Age difference in response time as a function of the percentage difference in line length judged as to which was the shorter The ordinate values represent the mean difference in response time between a young and an elderly group of subjects the abscissa represents the percentage difference between the lengths of pairs of lines judged (After Birren and Botwinick 1955)

these results However because of the constant age difference in response time when large differences in lengths of lines prevailed, factors other than perceptual difficulty are also regarded as operative

These findings led Botwinick *et al* (1958) to assess the effects of reduced stimulus exposure duration or discrimination response time Young (18–35 years) and old (65–79 years) were tested under conditions of the Birren and Botwinick study except that six percentage differences in line length were employed ranging from 1 to 20 per cent After tests with 2 second time as manipulated in this study as a source of increased perceptual difficulty

Also to be integrated into the theoretical considerations of Birren *et al* are the data of Platonoff (1911) He showed that on a test involving cancellation of letters older women (67–82 years) accomplished only 64 per cent as much work as did the younger group (21–41 years)

The importance of perceptual speed in influencing performance on tests of mental ability by different age groups has been emphasized by Lorge (1936), whose study is covered in chapter xx Relevant to the

present discussion is his conclusion that loss of speed with age is a factor that contaminates the relationship between intellectual power and age

Other studies which bear upon the general problem area of perceptual speed or difficulty and age appear elsewhere in this handbook The reader is directed to the research of Singleton (1955) on perceptual motor skills (chap xvii), to that of Clay (1954, 1956 1957) on factors affecting problem solving (chaps xvii and xx), and to that of Welford (1951, 1954, 1956) Welford s research has led to preliminary theorizing not unlike that of Birren and his associates (chap xvii)

XII Summary

This chapter has surveyed the status of our knowledge of perceptual processes in the elderly It is obvious that at this time, the total amount of information is not great

In the case of vision we know that acuity declines with age but that acuity may be improved by increased illumination Although the older eye benefits more than the younger eye from such heightened illumination, it never equals the latter in acuity After dark adaptation the absolute threshold for light is higher in older persons As length of dark adaptation increases, thresholds for old and young decline at the same rate Diminished visual efficiency is also demonstrated by the narrowing of the visual field in both light and darkness Critical flicker fusion declines with age in a linear and negative manner As brightness of light increases, the elderly show a greater relative increase and a smaller absolute increase in the fusion threshold The fusion threshold is not related to the light dark ratio, but a significant relationship with intelligence has been reported The data on age differences in color vision are inconsistent, and it may be that color vision correlates positively with acuity or that both depend on some common factor that is operating as the visual system ages

This picture of decreased sensitivity with age also prevails in the case of audition The incidence of deafness increases with age, and this finding has been explained in part by increasing inability to hear tones higher than 512 cycles per second

The study of age changes in the chemical sensitivities (taste and smell) has been all but neglected The absolute threshold for sweet has been shown to be highest in elderly subjects No other taste quality has been studied

Research on the cutaneous sensitivities—pressure, pain, cold, and warmth—has also been sparse, but, where it has been conducted, it has sought to determine absolute thresholds In corneal sensitivity, vibratory sensitivity, and pain sensitivity these thresholds increased with age The elderly are less able to maintain normal body temperature when exposed to cold and heat

From a basic research point of view, many significant sensory phenomena have not been related to aging In vision, these phenomena include light adaptation, saturation discrimination, after images, brightness contrast, and color contrast, to mention a few In audition, differential intensity discrimination, differential frequency discrimination, masking, and auditory fatigue are examples of other unexplored phenomena In the cutaneous, differential sensitivity and adaptation in the various modalities should be studied This observation also holds for the chemical senses, since only the absolute threshold for sweet has been determined

The study of age differences in perceptual processes or perception, where stimuli and responses are complex (i e, relatively not quantitative), has led to significant theorizing to explain at least one behavioral aspect of aging—the characteristic slow responses of the elderly Slowness or difficulty in perceiving the stimulus is assumed to constitute a major portion of this increased response time, and speed of perception is regarded as an important feature of mental activity In the investigation of age differences in perceptual speed, task or

discrimination difficulty has been varied, and response latency recorded Thus speed and accuracy of addition as a function of problem length have been studied, as well as judgment of differences of length of lines which are presented tachistoscopical ly The poorer performances of the elderly are interpreted as reflecting a change in a general speed factor underlying many per ceptual processes

Older individuals are, in general, less able to discriminate or recognize ambiguous stimuli and concealed and masked figures and these data can be integrated into the above theoretical considerations This lim ited theory could also guide further re search on other perceptual variables, for example, closure, figure ground relation ships, and illusions, as well as others

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XVII

Psychomotor Performance

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I Introduction

Psychomotor studies of aging form the meeting point of three sets of questions First, there are problems concerning the nature and causes of the obvious slowing of performance that comes with age To what extent are these changes attributable to the subject's sense organs and effectors, both of which are known to change with age—or must brain mechanisms also enter into any full explanation? There is an understandable reluctance to admit the latter we feel that a stigma attaches to impairment of brain functions, and therefore of mental life, which does not attach to impairments of other parts of the body, however disabling these may be Yet biological changes undoubtedly take place in the brain and will almost certainly have effects upon performance

Second, there are problems of whether 'age changes" in skills are due to inherent and essential aging effects, or whether they result from diseases and traumata which might be preventable if not reversible, or again whether they arise from attitudes built up in the course of experience which might be both preventable and reversible These are very difficult questions to answer, and it is probably not very profitable to attempt definitive answers at our present stage of knowledge Age changes must inevitably be the result of a constant interplay between the organism and what happens to it during its lifetime, so that it is seldom possible to unravel the precise contributions of one or another factor, at any rate in human studies

Third, research on human skills carried out during and since the second World War without regard to questions of aging has led to a number of insights and formulations which have revolutionized our outlook on sensorimotor performance and pointed to a number of fundamental factors and mechanisms We may well ask whether these vary with age and, if so, whether they provide a sufficient explanation of the age changes we observe There is not enough evidence for a definite answer yet, but the wartime and postwar research on skill has set issues for much future study of aging and can conveniently form the framework of our present discussion

The Concept of "Capacity"

Sensorimotor activity clearly involves not only sense organs and effectors but also a chain of brain mechanisms lying between them Both peripheral and central mechanisms have what may be thought of as a *capacity* which is limited both in the amount of data that can be handled at any one time and, perhaps more important, in the amount that can be dealt with in a given period of time In most circumstances the capacity of the peripheral organs, both sensory and effector, far exceeds that required by the task being done, so that the

limits of performance are set by the central mechanisms dealing with perception, with translation from perception to action, and with the detailed control of action At each stage we may think of neural signals occurring against a background of random neural activity Capacity is thus regarded in terms not only of available pathways but also of signal strength and its relation to the level of random neural noise' against which these signals have to be distinguished

Compensation for any loss of signal or lowering of signal to noise ratio can in part at least, be made by the integration of data over a longer time, and this could well be a reason for much of the slowness of performance which is observed under difficult conditions and also for slowness associated with old age If the extra time needed for such compensation cannot be taken, errors are likely to result Speed and accuracy can be related in the common measure of "information transmitted' in the 'information theory" sense of the term The rate at which information can be transmitted is limited, and errors such as those produced by hurrying are the result of too little information being transferred from signal to response

Further variables enter when we consider serial performance instead of discrete signal response units Among the simpler of these variables is the fact that perception and other events which occur during the reaction time following one signal can often overlap with the execution of the response to a previous signal, so that the over all time taken in a serial task is less than the sum of the various reaction and movement times involved Processes of discrimination and of choice of response seem also able to overlap, so that reaction time may be large

for those that follow, so that serial performance normally constitutes a feedback situation, with the subject behaving as an "error actuated servo"

"Higher" Units of Performance

On a rather more complex level we find that serial performance is built into "larger units" in the sense both that a single act of perception can follow the receipt of a long series of data and can initiate a series of actions and also that several signals and actions can behave as a single unit, with the whole "controlling" the individual parts Evidence of such control is contained in the fact that the larger unit may determine the speed at which the individual component actions are carried out. Anticipation and planning take place in terms of the larger wholes rather than of the individual parts When these units are well practiced, they tend to acquire the character of chain reactions in which each response becomes the signal for the next Initially, however, and in some cases permanently, they are more flexible the unit is not a stereotyped succession of actions but is aimed at an end result the means of achieving which vary with the precise details of the situation at the time Such flexibility is dependent upon the co ordination of data arriving at different times and would seem to lay stress upon processes of short term retention which hold earlier members of a series until they can be integrated with later members and keep a tally of what has been done and of what remains to be done

Flexibility also depends on the external conditions, under which a task is carried out, being such as to permit some variation in the way the task is done When they do so permit, the subject tends to compensate for difficulties and deficiencies in the sense that he adopts a method or manner of performance which optimizes the use of the capacities he possesses and the opportunities the environmental conditions offer him. Such compensation appears often to minimize the effects of aging Where, however, the form or pace of performance is rigidly determined, flexibility and compensation are reduced or absent, and the effects of aging and of difficult conditions are relatively severe

Limiting Factors

It is inappropriate to try to make categorical statements about whether psychomotor skill in general is or is not dependent upon one or another mechanism or to attempt crucial experiments with a view to establishing the universal importance of any one particular factor Adequate function of peripheral organs is a prerequisite for adequate performance but the subtleties of timing grading and patterning included in the term skill are obviously dependent upon central factors All we can ask is what function in any given circumstances *sets limits* to the performance Any link in the chain from receptor to effector and any mechanism concerned in the serial characteristics of performance may in certain circumstances limit the level of achievement It must be recognized that limits other than those within the individual s capacity may sometimes be important in this respect. Examples are expectations based on social norms or an individual s attitudes which may determine levels of performance well below the maximum that his capacities allow

Any limitation by one factor means that other capacities may change up to a point without there being any loss of achievement Admittedly performance will be carried on with progressively less ' margin in hand," and there will be a greater possibility of breakdown, but this will not occur except in unusual circumstances Thus measurement of maximum capacity in the laboratory may not always be an accurate guide to what is likely to be achieved in real life

II Limitation Due to Peripheral Mechanisms

Sense Organs

A number of well known changes in the structure of the eye and the ear associated with age have been outlined in chapter xv These obviously limit the performance of older people in some cases and may well do so more widely than is commonly recognized For example, they may, by reducing the strength of the signals arriving at the central mechanisms of the brain, result in these working more slowly and may thus place a strain on the means whereby data are integrated over periods of time We may further suspect that other, as yet seldom recognized, age changes to sense organs often influence performance Examples are the obscuring of vision due to "watering of the eyes" and changes in the vestibular apparatus leading to minor, although significant, difficulties of orientation.

The magnitude of age changes in the more elaborate forms of perception (e.g., Wallace, 1956) makes it unlikely that changes in the sense organs commonly exert much effect on psychomotor activity and suggest that the principal age changes of performance would remain even if means could be found of equating the sensory equipment of younger and older subjects Some attempts have been made to do this experimentally by equating subjects in different age ranges for performance in sensory tests Another possible line of research might be to produce artificially, by means of spectacles or other apparatus, conditions of sensory input for younger people that would simulate those of people in middle or old age

Peripheral Nerve Conduction

The time taken for impulses to travel along afferent and efferent nerves forms an appreciable although usually small component of a subject's total reaction time Reduction in the speed of nerve conduction, unless very severe indeed would therefore be unlikely to account for much slowing of actual performance with age Studies by several authors (Sommer 1941 Wagman and Lesse, 1952, Norris et al, 1953) have shown that changes in the velocity of impulses in human motor nerves do occur but are unlikely to account for more than about 4 milliseconds per metre

of the nerve involved Birren and Wall (1956) arrive at the view that little, if any, change with age occurs from young adulthood onward in the speed of conduction, length of refractory period, and number of fibers in the sciatic nerve of the rat, in spite of the substantially longer reaction times found by Birren (1955) among older rats to electric shock and to sound.

Effector Organs

MAXIMUM STRENGTH

Speakman (1956) in a survey of researches including those upon bodily strength found all studies in agreement that maximum strength as measured by brief tests is highest in the twenties, after which there is a decline. The results of several studies using various muscle groups are summarized in Table 1. They have also been elegantly shown in graphical form by Fisher and Birren (1947).

CONTINUOUS EXERTION

Burke *et al.* (1953), whose results for maximum strength of grip are shown in Table 1, found that the average grip that can be maintained over a period of 1 minute on a hand dynamometer showed a proportional decline with age which was nearly identical with that for maximum grip.

Research upon the effects of intensive muscular effort in relation to age have used very tiring work carried out for a

TABLE 1

MAXIMUM STRENGTH AT DIFFERENT AGES AS A PERCENTAGE OF STRENGTH AT AGES 20–29

Author and Muscle Group	Age Range 20–29	30–39	40–49	50–59	60–69	70–79
1 Uffland (1935)						
Grip, right hand	100 (41.6)*	96.4	90.9	78.0	64.9	
Biceps right flexor	100 (31.8)	93.4	83.6	66.0	54.1	
Wrist, right flexor	100 (29.3)	96.9	93.1	85.9	75.4	
Thumb right flexor	100 (12.4)	96.8	96.8	85.3	79.8	
Wrist, right extensor	100 (24.3)	99.2	94.2	88.9	79.3	
Back strength	100 (134.6)	95.4	89.8	79.2	64.3	
2 Galton see Ruger and Stoessiger (1927)						
Grip, right hand	100 (37.4)	99.8	97.8	93.2	85.9	74.9
Pull (across chest)	100 (33.7)	99.4	95.1	87.9	78.0	65.5
3 Cathcart *et al.* (1935)						
a) Employed men						
Grip right hand	100 (52.7)	99.4	96.3	91.3	82.2	
Back strength	100 (171.6)	100	97.0	93.1	85.3	
b) Unemployed men						
Grip right hand	100 (46.1)	97.1	94.1	87.2	80.9	
Back strength	100 (150.2)	99.3	93.7	87.7	84.9	
4 Burke *et al.* (1953)						
Maximum grip strength	100 (56.3)	95.0	91.5	86.9	78.8	64.4

Author and Muscle Group	Age Range 23–27	28–32	33–37	38–42	43–47	48–52	53–68
5 Fisher and Birren (1947) Grip, right hand	100 (56.0)	96.8	95.2	93.5	89.9	86.2	83.6

* Numbers in parentheses are kilograms

brief period—up to about 30 minutes These studies commonly show that with increasing age there is a decline in the amount of work done in a given time or until some criterion of exhaustion is reached (e g, Szakall 1944)

Other studies have shown that the rate of oxygen intake falls both during maximum work and during periods of rest (Robinson, 1939) elimination of carbon dioxide slows down from the twenties onward (Berg 1947) and exercise produces less increase in pulse rate among older people than it does among younger (Simonson 1947) The evidence would appear to mean that age changes in the mechanisms of respiration and circulation are such as to reduce the physical capacity of the organism for heavy muscular exertion and the reserve which can be drawn upon to meet peaks of demand for physical effort

On the other hand recovery from oxygen debt appears not to be impaired with age (Berg, 1947), and mechanical efficiency changes relatively little except at very high and very low rates of work (Norris and Shock 1955) These authors suggest that the lower efficiency at low rates of work may be due to poorer muscular co-ordination on the part of older subjects As this co ordination is the result of kinesthetic and other sensory feedback the inefficiency must be reckoned as the result and not the cause of poorer sensorimotor performance

The physiological evidence would seem to make understandable the well known observation that middle aged people sometimes show an endurance in athletic performance at least equal to that of younger The younger man s special race seems to be the short sprint and in this the older performer cannot compete Long distance runners whose performance depends less upon the capacity for short term peak output have upon many occasions shown a high performance as late as the forties

Maximum strength and capacity for continued exertion may well be important factors limiting energetic pursuits and work involving heavy muscular effort by older people The limits of capacity seem, however, to be of little importance in most everyday activity until a great age is reached, although they may perhaps sometimes affect willingness to undertake active pursuits

OTHER POSSIBLE EFFECTOR FACTORS

Some subtle limitations, for example stiffness of joints leading to difficulty of action or reduced mobility of the neck resulting in the need to turn the whole body to see sideways, doubtless affect some sensorimotor performances, although the extent to which they do so has not, so far as the author is aware, been studied There are also factors which enter into gait and posture, which show well known changes with age Their effects on some tasks may be substantial, but again it seems likely that, compared with central factors, the limitations imposed are relatively small

III REACTION TIMES

The reaction time, which classically is taken as the period elapsing between the appearance of a signal and the beginning of a responding movement, is traditionally regarded as a measure of the time taken by central processes Obviously, it includes some time taken by peripheral processes as well, but, as we have seen, this is usually short compared with that taken by perception, translation from perception to action and the shaping and initiation of the responding movement The central processes which take place during reaction

Measurements of Discrete Reaction Times

We shall discuss first the results of experiments in which each reaction time is measured separately The subject is given a ready signal, and this is followed at an

interval of time (the "foreperiod") by a signal to which the responding action must be made as quickly as possible There is no doubt that this type of measurement usually leaves out of account much that goes on in the foreperiod which may be significant, but whether it is of importance in determining age changes is not clearly known This disadvantage can be overcome to some extent by measuring serial reaction times These will be considered later

The results of various studies of simple reaction time are summarized in Table 2 All have found that reaction times tend to lengthen with age but that the amounts by which they do so are usually small This may partly be due to the older subjects' not having been truly comparable with the younger Galton's subjects, for example, were visitors to an international health exhibition who volunteered to be tested, and it is likely that only those older people who were more alert and robust than normal offered themselves for this purpose Some confirmation that this was so is contained in the fact that numbers in his older groups were very much lower than in his younger The studies do, however, leave little doubt that slowing with age at these very simple tasks is relatively slight Not only do they agree fairly well among themselves but even those in which the age trend is relatively large show less slowing than many of the studies to be reviewed later

COMPARISON OF THE EFFECTS OF SIGNALS IN DIFFERENT SENSORY MODES

Some of the studies included in Table 2 have compared visual and auditory reaction times in different age ranges Auditory reaction times are slightly shorter on average than visual at all ages There is no real evidence for any differential decline with age between reaction times to signals in the two sensory modes This would indicate that the sense organs do not limit performance in these cases unless, on average, they do so equally

COMPARISON OF THE EFFECTS OF RESPONSES BY DIFFERENT EFFECTORS

Results comparing the reaction times for hand and foot obtained by Miles (1931*a*) have been given in Table 2 Figure 1 shows results obtained by Miles (1931*b*) from a much larger sample using the same methods Those for "pursuit reaction" do not concern us at the moment The hand reaction times show, as we have noted, remarkably little change until the seventies Those for the foot show rather more change with age, but the difference is still small

Similarly, small differences of change with age were found by Birren and Botwinick (1955*a*) between reaction times for finger, jaw, and foot in response to a 1000-cycle tone presented through earphones Their results are given in Table 3 and show that, while their older group reacted more slowly with all three members, the difference between the times taken by the younger and older subjects was about the same in all cases The fact that the lengths of peripheral nerve path were very different in the three cases confirms that age changes in reaction times are not due to slowing of the rate of peripheral nerve conduction

LENGTH OF FOREPERIOD

Several studies which have not been related to age have shown that reaction times can be substantially affected by the length of the foreperiod preceding the signal There seem to be two distinct factors involved First, during the foreperiod the subject usually seems to make some preparation in anticipation of the signal, and this leads to a shorter reaction time if it can be made at just the right moment before the signal arrives To do so, he must judge the length of the foreperiod on the basis of experience gained in previous trials When the foreperiod is of irregular length, this means that he will adjust his preparations for something like the median or the modal interval and will be unprepared if the signal arrives sooner Reaction time

TABLE 2*

SIMPLE REACTION TIMES
(In Seconds)

Author	Type of Reaction†	Teens	Twenties	Thirties	Forties	Fifties	Sixties	Seventies	Eighties	Notes
Galton (1899), see also Koga and Morant (1923)	Press key in response to light	0 187	0 182	0 181	0 190	0 186	0 206	0 205		Subjects were visitors to an international health exhibition The figures have been calculated approximately from those given by Koga and Morant
	Press key in response to sound	158	154	158	159	157	167	174		
Miles (1931a)	Press key in response to sound		23	24	22	20	28	30	0 28	100 subjects fewer in the twenties and eighties than other ranges The twenties ranged from 25 to 29 only Data from a much larger sample are given in Fig 1
	Release key in response to sound		21	22	22	22	23	26	28	
	Lift foot in response to sound		22	22	24	24	26	27	30	
Bellis (1933)	Press key in response to light									20 subjects in each age range except the highest which had 10 Equal numbers of men and women in each range Scores are means of best five readings by each subject
	Men	24	22	26	27	38				
	Women	32	26	34	36	44				
	Press key in response to sound in headphones									
	Men	23	19	24	25	37				
	Women	31	20	30	30	42				
De Silva (1936)	"Brake reaction time" in a test designed to simulate car driving (subject raised foot from accelerator pedal and transferred it to brake on seeing red flash of a traffic light)	418	418	428	442	455	465			2000 subjects The age range of the teens is 16–19 and of the sixties, 61–65 The figures are approximate only, having been taken from a graph included in De Silva's paper
Fieandt *et al* (1956)	Pressing button in response to light	0 228	201	201	217	212	217	0 245	0 353	The age ranges were 11–14 21–24, 29–36, 39–47 49–56 59–67, 69–79, and 80–88 Each of the 120 subjects gave five readings The two extremes of these were excluded and the scores were the means of the remaining three
Cesa-Bianchi (1955)	Response to light		215	186	202	207	214			268 subjects mostly between 30 and 59 The oldest age range was 60–66 Very full scores given for individual subjects
	Response to sound		0 157	0 161	0 179	0 167	0 187			

* See also Table 3

† All are made with the hand unless otherwise stated

will thus be longer after very short fore periods It seems also frequently to be a *little longer following very long foreperiods* There are probably two causes of this according to whether the foreperiod length varies from trial to trial or remains the same throughout a series In the former case the subject will be optimally prepared for a foreperiod of moderate length, and, if the signal does not arrive when expected, some of this preparation may be lost In the latter case accurate judgment of the time of the foreperiod interval, on which optimal preparation will depend, is likely to become more difficult as the foreperiod becomes longer

Where the foreperiod is very short, a second factor is likely to enter It has been shown in serial reaction tasks that, when one signal comes very soon after another, reaction to the second may be delayed because some processes concerned with responding to the first signal have to be completed before reaction to the second signal can begin (see Welford, 1952, and the references there given, also Davis, 1956, 1957) *In some cases the cause lies* in the actual responding movement to the former signal not being finished in time, but in others it is due to the central mechanisms still being 'busy" with "attending to" the former signal It appears that the central mechanisms make decisions or deal with signals (or groups of signals) one at a time and that, if a new signal arrives while the former one is being dealt with, it has to 'wait" until the central mechanisms are free The central mechanisms may be

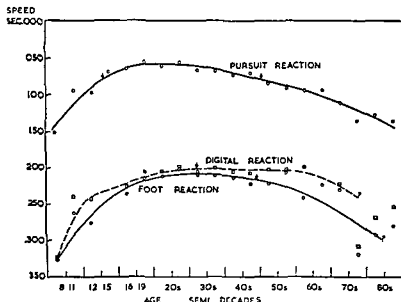


FIG 1 —Results obtained by Miles (1931*b*) for three reaction tests

TABLE 3*

SIMPLE AUDITORY REACTION TIMES OF FINGER, JAW AND FOOT

(In Milliseconds)

	AGE GROUPS (32 SUBJECTS IN EACH)		DIFFERENCE BETWEEN AGE GROUPS
	19 36	61 91	
Finger	182	232	50
Jaw	194	254	60
Foot	202	260	58

* From Birren and Botwinick (1955*a*)

engaged not only by signals but also by the monitoring of responses, and this latter engagement may last for a time beyond the point at which the overt response has been completed

Both types of factor may have operated in the results obtained by Botwinick *et al* (1957) which are shown in Figure 2 The subjects were required to press a key at a warning signal and to release it again on hearing a tone The interval between the warning and the tone (i e, the foreperiod) was varied in a quasi random manner for successive responses It can be seen that the reaction times (between the onset of the tone and the release of the key) of the older group were longer than those of the younger with all lengths of foreperiod but that older subjects showed some extra slowing with foreperiods of 2 5 seconds and less

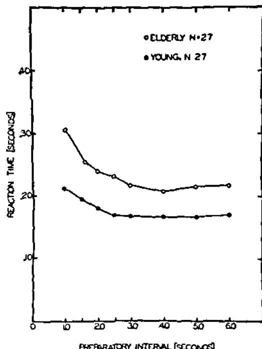


FIG 2—Reaction time and foreperiod interval Means of the median values of individual subjects Elderly subjects were aged 61–83 years, and the young 20–36 years (After Botwinick *et al*, 1957)

It is this extra slowing that is of interest. The times required to observe the "ready" signal and to press the key in preparation for the tone would almost certainly have been longer for the older subjects than for the younger We might thus have expected them to have caused greater lengthening among the older than among the younger subjects of the reaction times following the shortest foreperiods (say, 1 0 and 1 5 seconds) As the times taken to observe the warning signal and press the key are likely to have varied from trial to trial, they would probably *on average* have caused some lengthening with foreperiod intervals somewhat longer than 1 5 seconds

The extra time taken by older subjects, especially with these longer foreperiods, may well, however, have been due, at least in part, to some of the less tangible aspects of 'set" included in the first of the two types of factors outlined Older subjects may, for example, have been more influenced than younger by preceding foreperiods, and the lengthening of reaction times with very short foreperiods may thus have been due to the fact that in a quasi random series short foreperiods are, on average, preceded by longer ones Evidence of this kind of "set" has been produced in an experiment by Klemmer (1956) not related to age and has been found related to age in studies of *perception* by Verville and Cameron (1946), Wallace (1956), and O Doherty (see Welford, 1958)

EFFECT OF MOTIVATION

The slowness of older people is sometimes attributed to lack of motivation on their part Evidence against this view is contained in an experiment by Botwinick *et al* (1958*a*) Thirty subjects aged 65–79 and thirty aged 18–37 each made twenty four

an electric shock to the wrist if he took longer than his own median time for the first twenty four reactions If slowness by older subjects in the first series had been due to lack of motivation, it might have

been expected that they would show a greater proportionate improvement than younger subjects in the second series The results in Table 4 show that both groups became, on average, faster in the second series but that the older subjects did not become proportionately more so than the younger

Discrimination and Choice Reaction Times

Important researches by Hick (1952*a*, 1952*b*), Hyman (1953), and Crossman (1953) have indicated that choice reaction time is roughly proportional to the amount of "information" (in the information theory sense of the term) transmitted from the display or signal source to the responding action It is, therefore, linearly related to the logarithm of the number of equiprobable choices or their equivalent Hick's formulation may be expressed as $T_R = k \log n_e$, where T_R = reaction time, n_e = the effective number of equiprobable choices,[1] and k is a constant The value of k, and possibly also the whole validity of the formulation, seems to depend very much upon the nature of the relationship between the signal and the responding action required Where this involves the interpretation of a symbolic display, such as deciding which of several reaction keys to press according to a digit presented on a screen, k appears to be large, and the reaction times for different numbers of choices are thus very different. When the relationship is more direct, as, for example, if the signal lights are placed immediately above the reaction keys, k is small, and other factors which enter into reaction time may obscure the relationship between time and degree of choice There is, indeed, evidence that, if the stimuli can be given directly to the responding members so that in effect no translation from sight to action is required, the relationship breaks down completely, and responses are equally fast whatever the degree of choice (Leonard, 1959)

Crossman (1955) has shown that a different formulation is required for the effects of different degrees of discrimination, and he suggests the following as accounting for the results both of previous authors and of his own work $T_D = c/(\log x_1 - \log x_2)$, where T_D is the discrimination time, x_1 and x_2 are the quantities being compared, and c is again a constant

TABLE 4*

REACTION TIMES† WITH AND WITHOUT ELECTRIC SHOCKS AS 'PUNISHMENT' FOR SLOW REACTIONS

	AGE GROUP	
	18 37	65 79
Without shocks	177	233
With shocks	157	220
Difference	20	13
Difference as percentage of 'without shock' time	11 3	5 6

* From Botwinick *et al* (1958*a*)

† Times are in milliseconds and are the means of the individual subjects median times

It seems to be a very pertinent question to ask whether these times for choice and discrimination increase proportionately with age—in other words, whether age changes can be described as an increase of k or c

The earliest evidence appears to be that of Goldfarb (1941) His subjects sat pressing a button in the center of a semicircle of five keys Immediately beyond each key

[1] n_e may equal the number of possible equiprobable signals or this number plus 1, according to whether the possibility of 'no signal' has to be considered by the subject In cases where signals are of unequal frequency the formula may be written

$$T_R = k \sum_{0}^{n} (-p_i \log p_i),$$

where p_i is the probability of occurrence of the ith signal

was a light The subject was given a warning sound (a click), and then between 2 and 4 seconds later (the interval was varied randomly) one of the lights would come on The subject was required to move his hand as quickly as possible from the central key to the key under the light. Four groups of twenty five trials were given The first and last contained simple reactions using only the center light, the second involved two choice reactions using the lights on either side of the center in random order and the third involved five-choice reactions using all the lights, again in random order All the subjects were men

Three recent experiments by Crossman and Szafran (1956) have used sorting tasks to study times taken at different ages for varying degrees of choice and fineness of discrimination These tasks provide essentially serial reaction time studies In their first experiment discriminability was held approximately constant, with degree of choice systematically varied The subject sorted an ordinary pack of playing cards into either red or black, the four suits, or the four suits separating court cards from the others These arrangements provided two, four, and eight choices, respectively As a control, the cards were dealt alternately into two piles to give a measure of time taken to make the movements of sorting without having to make discriminations or choices

TABLE 5*

COMPARISON OF SIMPLE AND CHOICE REACTION TIMES
(Mean Times in Milliseconds)

	Age Group				
	18–24 ($N=22$)	25–34 ($N=27$)	35–44 ($N=23$)	45 54 ($N=22$)	55–64 ($N=14$)
Simple	376	321	334	366	387
Two-choice	394	380	395	436	451
Five-choice	429	418	432	472	495
Difference between simple and two-choice	18	59	61	70	64
Difference between two-choice and five-choice	*35*	*38*	*37*	*36*	*44*

* From Goldfarb (1941)

The results are shown in Table 5 The mean simple reaction times rise by about 20 per cent from the 25–34 to the 55–64 age group This is somewhat higher than the rises in most of the results tabulated in Table 2, perhaps because of the greater amount of movement required in Goldfarb's experiments

The choice reaction times are, as expected, longer than the simple times at all ages The rises with age do not, however, seem to be proportionate Rather it looks as if the effect of choice is to add a constant to the reaction time at all ages In other words, the change with age is not in terms of *k*

The second experiment involved sorting into two piles special packs of cards carrying randomly arranged dots In different packs there were equal numbers of cards bearing two different numbers of dots ranging from 1/4 in the easiest pack, *through* 6/12 and 8/12 to 8/10 The third experiment involved sorting a row of small metal canisters into two categories by weight, the ratio of the weights being varied in different trials

The results of these three experiments

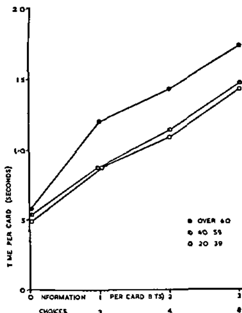


FIG 3a —Experiment I The average times of different age groups for sorting playing cards into different numbers of classes Each point is the mean of about 20 subjects 3 trials per subject 52 cards per trial (After Crossman and Szafran 1956)

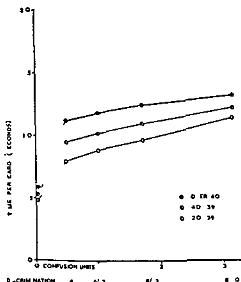


FIG 3b —Experiment II Times for sorting cards into two classes, with different degrees of discriminability (After Crossman and Szafran, 1956.)

are set out in Figure 3 In all of them the time taken by the youngest group rose lin early as the degree of choice or the fineness of discrimination increased The times taken by the older groups did not, however, rise proportionately For the condition in which no discrimination or choice was needed, there was little difference with age When choice was required, it appeared that, as in Goldfarb s experiments, a con stant extra time was taken by older people regardless of the degree of choice involved

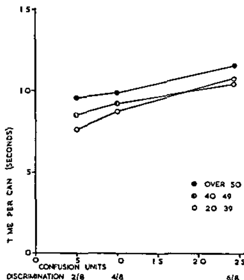


FIG 3c.—Experiment III Times for sorting weights into two classes with different degrees of discriminability (After Crossman and Szafran 1956)

With varying discrimination the extra time taken by older subjects compared with younger appeared actually to diminish as the difficulty of the task increased It seems therefore, that the slowing with age in these cases again cannot be described in terms of an increase in the term k or c in Hick s and Crossman's formulas

Crossman and Szafran, in commenting on their results put forward a theory in terms of neural ' noise increasing with age. They say

The three tasks chosen are similar in that in each a choice must be made between a small

number of possible actions, the alternative signals for which are easily perceived The ef fect of age is to slow up performance very ap proximately in inverse proportion to the diffi culty of discrimination and independently of the degree of choice above a certain minimum We may imagine that the process of discrimina- tion is carried out by the brain in the following way The presented signal is compared with a remembered representation of each possible al- ternative and the one to which it most closely corresponds is selected The comparison must be in the nature of a statistical test between

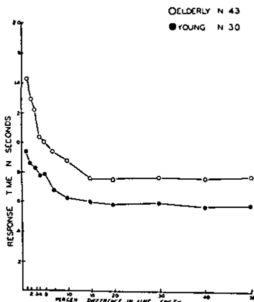


FIG 4—Times taken to judge differences in lengths of line (After Birren and Botwinick 1955*b*)

several hypotheses, made on the basis of an incoming stream of samples

The difficulty of deciding between the hy potheses that is of identifying the signal de pends (Crossman 1955) on the ratio between them the more different the signals are the easier being the discrimination, a longer inte gration time is needed to discriminate finer dif

eing

are

s If

we suppose that a random disturbance is added to all signals before discrimination exactly this effect would be produced for the ratio would

tween signals or states In physiological terms the noise might be an increased rate of spon taneous firing of neurones, or an increased like lihood for neighboring neurones to excite one another by non synaptic pathways

The hypothesis of internal noise has been put forward to account for the existence of absolute sensory thresholds [see Gregory and Cane, 1955, Gregory, 1956], and as it is well known that absolute thresholds increase with age a simple increase in the noise level would also account for the findings [Crossman and Szafran, 1956, p 133] [See also Gregory, 1959]

Crossman and Szafran's results at first sight run counter to those of Birren and Botwinick (1955*b*), who measured times taken to judge which was the longer of pairs of lines Their results are set out in Figure 4 and show not only that do the older subjects take longer with all degrees of discrimination but that they take pro- portionately longer as the difference be tween the lines becomes smaller These finer degrees of discrimination were, how ever, beyond the range of those used by Crossman and Szafran It would seem therefore, that, although age differences of reaction time are little related to degree of discrimination at levels well above thresh old, they may be so related as levels ap- proach threshold

The interpretation of Birren and Bot winick's results is, however, in some doubt following further work by Botwinick *et al* (1958*b*) The latter authors compared the conditions of Birren and Botwinick's study in which the lines to be compared were ex posed for 2 0 seconds with conditions in which they were exposed for only 0 15 sec ond The accuracy of the finer discrimina tions fell sharply with the shorter exposure but did so approximately equally for both younger and older subjects The surprising fact was that, while the times found using

proportionate rise with age as the discrim ination became finer The results are set out in Table 6 It seems possible that, with the

longer exposure, the older subjects took time checking and that the proportionate rise with age was in the time required to attain *certainty* rather than *accuracy*. Such an explanation can, however, at present be no more than speculative.

Time can be saved at the expense of accuracy, so that a lowering of performance with age can show either in slowness or in decreased accuracy or in both. In the cases surveyed so far accuracy has been very similar at all ages, and age changes have been shown by slowing of performance. An experiment is reported by Pacaud (1955*a*, 1955*b*), however, in which the age change in a choice reaction task appeared as an increase of errors. The times have not been published, but the author understands that they also increased with age, so that there was no question of the errors among older subjects being due to faster performance. The experiment was one of a battery tried on some four thousand apprentices and operatives on the French railways. Subjects were required to

1. Press with the left foot on seeing a red light.
2. *Raise the right foot on seeing a green light.*
3. Make both movements on seeing a yellow light.

When these responses had been learnt the task was further complicated by the requirement that when a light signal was accompanied by a sound of metallic quality a key was to be

TABLE 6*

REACTION TIMES AND ERRORS IN JUDGING WHICH OF TWO LINES IS THE LONGER

Age Group†	Time for Which Lines Exposed (in Seconds)	Percentage Difference between Lines					
		1	2	3	5	10	20
		Reaction Times (Means of Individual Subjects' Medians) in Seconds					
65–79	2.0	1.51	1.42	1.25	1.12	0.91	0.92
18–35	2.0	1.08	1.05	0.95	0.84	0.73	0.72
Difference		0.43	0.37	0.30	0.28	0.18	0.20
Difference as percentage of younger		40	35	32	33	25	28
65–79	0.15	1.06	1.01	0.97	0.89	0.84	0.82
18–35	0.15	0.88	0.87	0.80	0.73	0.68	0.67
Difference		0.18	0.14	0.17	0.16	0.16	0.15
Difference as percentage of younger		20	16	21	22	24	22
		Percentage Mean Errors					
65–79	2.0	16	8	5	2	0	1
18–35	2.0	14	7	0	2	0	0
65–79	0.15	30	29	19	14	3	1
18–35	0.15	28	28	11	6	0	0

* From Botwinick *et al.* (1958*b*).

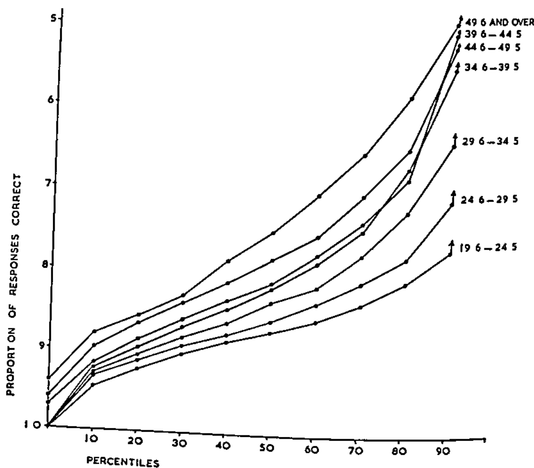
† There were 34 subjects in the older age group and 26 in the younger.

pressed and the normal reaction to the light omitted When the sound was of a lower tone however the subject had to respond as to the l ght signals above

Performance at this task fell steadily and substantially from the early twenties on ward as shown in Figure 5 The fall was much less when responses were required to the light signals alone and the sound sig nals were omitted The task was, formally, one of choice reaction and discrimination, but it seems clearly to have had unusually confusing features which may link it to the kinds of task discussed later

VARIABILITY

It is commonly found in a wide variety of performances that individual differences rise with age, so that the scatter of read ings is very much greater in older age groups, and many older subjects perform at a level at or above the mean of those much younger This point is stressed by Miles (1931b) in relation to his own re sults and the same has been found in many, although not all of the other stud ies reported so far In some cases where it has not been found, this may be due to the method of measurement adopted, for ex



ample, Bellis (1933) used only the best five readings from each subject

Why this increased variability should occur in old age is not certainly known, and three possible reasons have been suggested The first is that people age at different rates, so that a sample of a given chronological age in later life will include people of widely varying biological ages A second possibility is that performance in the younger groups is limited by some factor which masks age changes of capacity until these have become relatively severe Once they have so become, however, they affect performance to an extent which increases rapidly with age Any variation in the rate of aging will thus produce wide differences between individuals from the time that the masking factor and capacity come together the performance of some individuals will still be limited by the masking factor, while that of others will show substantial change The third possibility is that experience channels interests and skills more narrowly as a man or woman grows older, so that some things are done better, while others are not done so well Since experience is highly individual this will make for diversity of performance at any one task by a group of subjects

Goldfarb (1941) found that the variation between his subjects' mean reaction times and the variation within each subject's times tended to increase with age, although not quite regularly He however, had no subjects over 64 years of age

Obrist (1953), in a study of simple auditory reaction time among subjects 18–39, 65–75, and 76–86 years of age, found a clear increase with age in the variability between subjects and between the different readings given by the same subjects His results are shown in Table 7 The second type of variability would seem to need an explanation different from the first It suggests that with age goes an increased randomness in the time taken by the various mechanisms to act What the cause of it is we can only conjecture, although it is tempting to regard it as another result of neural "noise"

Obrist's finding ties in well with the earlier one of Miles on what he termed "pursuit reaction" Miles's subjects attempted to stop the hand of a clock rotating twice per second at a zero position by pressing a key The errors made by different age groups clearly increased with age from the twenties onward The task was not one where speed was of importance, because the subject could initiate his action well in advance of the zero point Accuracy depended upon the predictability of the time between his initiating the decision to press the key and his pressure becoming effective in stopping the clock Any randomness in this time meant that its predictability was lowered, and an increase of randomness with age could have accounted for Miles's results

TABLE 7*

CHANGES IN THE VARIABILITY OF SIMPLE AUDITORY REACTION TIMES
(In Milliseconds)

	Age Group		
	18–39	65 75	76–86
Variation between subjects (standard deviation of median readings)	10 6	16 4	22 2
Variation between readings (mean of the semi interquartile ranges for the individual subjects)	9 3	11 0	14 0
Mean reaction time (mean of the medians for the individual subjects)	122	131	145

* From Obrist (1953)

Reaction and Movement Times

Miles (1931*b*), in addition to the times shown in Table 2 and Figure 1, took a number of what he termed "motility measures," which included a "digital extension-

flexion test in which the forefinger of the dominant hand was raised and lowered as quickly as possible to operate a Morse key, turning the crank of a hand drill mechanism as fast as possible first with the dominant hand and then with the other, and a complex movement entitled manual reach and grasp which consisted of raising the finger from a key transferring a pencil from one hole to another and moving the hand back to the key *The results are* shown in Figure 6 Comparing this with

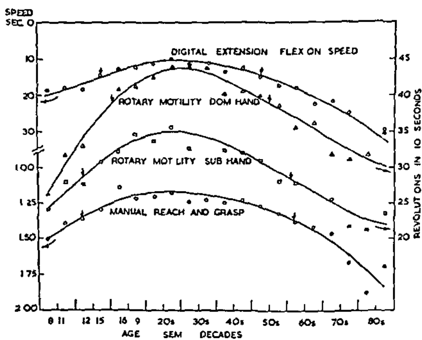


FIG 6 —Results obtained by Miles (1931*b*) for four motility measures'

Figure 1 the age changes in the motility measures seem to be greater and to start sooner than they do in the reaction times It might be inferred from this that the main locus of slowing with age in sensori *motor tasks was in the execution of move*ments as such

Evidence is however conflicting Results seeming to favor such an interpretation have been provided by an experiment by Pierson and Montoye (1958) The subject s task was upon the lighting of a neon bulb, to lift his hand from a microswitch and to thrust it forward as fast as possible through a light beam 11 inches in front. The secon tion . . . and the release of the microswitch and the movement times between leaving the microswitch and interrupting the beam are plotted in Figure 7 It can be seen that the change of movement time from the twenties onward was substantially greater than *the change of reaction time*

Several other experiments, however, have . . . ther evidence is contained in a series of experiments in which reaction times and movement times were *both measured* separately

The first of these was by Szafran (1951) The subject sat in a kind of cockpit facing a panel of small lights and with targets—one corresponding to each light—around him at nearly arm s length As soon as one of the lights went out, the subject had to move a stylus from a small metal plate di

rectly in front of him to the corresponding target The experiment was performed under two different conditions, one with full vision and one with the subject wearing goggles which left the lights visible but obscured everything else For our present purpose the difference between these two conditions is unimportant The interesting result is that, while the time between the light going out and the subject lifting the stylus from the plate rose with age, the actual movement time between leaving the plate and reaching the target did not The results are contained in Table 8 They have since been confirmed in an experiment by Griew (1959) mentioned in the next section

The second experiment, which was by Leonard (1952), compared groups of subjects in a serial reaction task where the subject sat facing a display panel with five neon bulbs at the corners of a regular pentagon On a table in front of him was a board with a 1¼ inch diameter brass disk

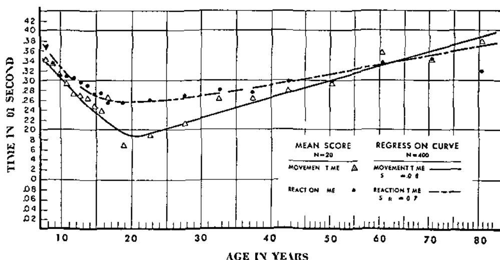


FIG 7 —Smoothed curves for movement time and reaction time in relation to age based on group means (After Pierson and Montoye 1958)

TABLE 8*

REACTION TIMES AND MOVEMENT TIMES IN AN AIMING TASK
(In Seconds)

	Age Group			
	Twenties	Thirties	Forties	Fifties
Time from appearance of signal to beginning of responding movement	0.86	0.99	1.29	1.37
Duration of responding movement	1.18	1.20	1.14	1.22

* From Szafran (1951)

corresponding to each light bulb and another similar disk in the center with its edge $1\frac{3}{4}$ inches from the inner edges of the other disks The task was presented under two conditions In one condition the subject slid the stylus from the center disk to one of the other disks indicated by the corresponding light being on, he then returned to the center disk as quickly as possible, whereupon the light changed, indicating that the stylus should be moved to a different disk and so on for a series of a hundred signals In the other condition the task was similar except that the light of the lights came on, he should make the responding movement as fast as possible The light went out when he reached the end of the correct slot, and the next light came on as soon as he returned to the center Considerable care was taken to insure that the time spent at the center was an accurate measure of reaction time Singleton's results are given in Figure 9, from which it will be seen that there was a small (although highly consistent and significant) rise with age in the time spent at the center, a slight fall as far as the fifties in the time spent moving and at the end

TABLE 9*

ANALYSIS OF CYCLE TIMES IN A SERIAL-REACTION EXPERIMENT
(In Seconds)

	Light Changing When Center Disk Touched		Light Changing When Indicated Disk Touched	
	Twenties	Sixties	Twenties	Sixties
Total time per cycle	0 85	1 24	0 69	1 10
Made up of				
Time on disks	59	0 92	38	0 79
Time moving between disks	0 26	0 32	0 31	0 31

* From Leonard (1952)

changed as soon as the indicated outer disk was touched, thus providing the subject with advance information of the direction in which he would have to move after returning to the center Leonard's results are given in Table 9 It can be seen that the older subjects took substantially longer than the younger but that practically the whole of the extra time was spent on the disks The times spent actually moving were closely similar for both younger and older

The apparatus for the third experiment, which was by Singleton (1954, 1955), is shown in Figure 8 The subject sat with the upright joystick between his knees and had to move this over a distance of about 4 inches in slots—forward, back, left, and right—in response to lights appearing at the ends of the arms of the cross on the display His instructions were that, when one point, and in the sixties a small rise of actual movement time with a substantial rise of time spent at the end point

A fourth experiment, also by Singleton, used similar apparatus but involved two choices only and a more complicated movement in which, for each response, the subject had to pull a lever toward him, push it to one side or the other, and then return by the same route The time spent at the points where the lever was stationary, that is, (1) at the center, (2) where the direction changed between the initial movement toward the body, and the movement sideways and (3) at the end point, are shown in Figure 10, as also is the time for movements between these points Once again we see that it was the time spent between movements, rather than in making them, that rose with age

These four experiments indicate that, at

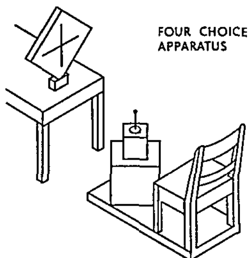


FIG 8 —Apparatus used by Singleton (1954) for a serial reaction task

least until the forties or fifties and perhaps in some cases beyond, the actual times spent making movements do not rise, or rise very little, with age Slowing of performance occurs mainly during those portions of the task where signals are being perceived and responding actions are being prepared—in other words, during the reaction times

In experiments such as those of Singleton, which measure serial reaction times, it *is difficult to be sure whether any length*ening of the time is due to processes concerned with the initiation of a responding movement or with processes which are in some way an aftermath of a previous movement Some check upon this point was made in an experiment by Jeeves, using Singleton's four choice apparatus but introducing brief delays between the subject

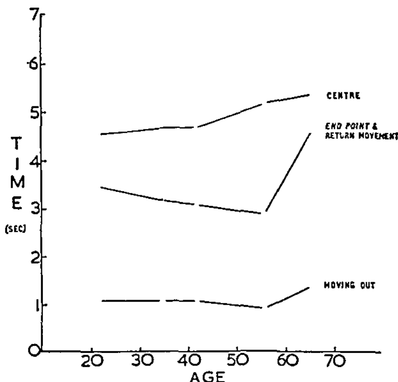
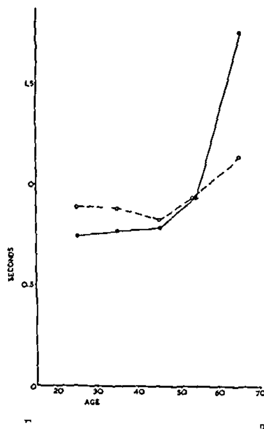


FIG 9 —Component times in a four-choice serial reaction task (After Singleton, 1955)

reaching the center and the signal light for the next response coming on (see Welford, 1958). If the time spent at the center is taken up with processes following the previous movement, these should be able to take place during the delay period, and, so long as the delay does not exceed the time taken by these processes, the total time at



ing (After Singleton 1955.)

the center should not be increased. If however, center time is entirely taken up with processes of responding to the signal and with initiating the ensuing movement, it will be increased by the amount of the delay. Jeeves's results are set out in Table 10. The reaction time for both younger and older subjects fell somewhat from the condition in which there was no delay to that in which some delay was present, but changed little from a delay of 0.1 second to one of 0.2 second. It thus seemed clear that, although some of the center time in Singleton's experiments might have been attributed to processes following previous movements, this was not the main, and certainly not the only, cause of the lengthening of the center time with age that he found.

Jeeves's results sound a warning against oversimple concepts of sensorimotor performance. We may note from Table 10 that the delay affected not only the center times but the whole pattern of performance as shown by the outward movement times and the times spent at the end point and making return movements. Why these other changes should have occurred is not clear, but it emphasizes that even relatively simple tasks involve complex co-ordination of sensory and motor functions. To these co-ordinations we must return later.

The conflict between Miles's results and those of Szafran, Leonard, and Singleton would be resolved if older people are less able than younger to overlap the planning of one movement with the execution of a previous one. This would impair the co-ordination in the performance of Miles's tasks and would also account for the relatively long times spent by the subjects in the other experiments between completing one movement and initiating the next. This explanation would not resolve the conflict with Pierson and Montoye's results. It is possible that the explanation of the longer movement times they found were due to their older subjects making the movements more carefully and meticulously than the younger. As will be seen in a later section older people seem to have a spontaneous tendency to care and accuracy.

Whether or not these explanations are true, the effect of these rapid movements with relatively long times spent between them in Leonard's and Singleton's experiments was to make the performances of older subjects look somewhat jerky and lacking in what appeared among younger subjects as a flowing rhythmical quality.

REACTION TIME AND THE COMPLEXITY OF RESPONDING ACTION

Miles (1931*a*), in the study the results of which are given in Table 2, found that, although reaction to sound by raising the finger from a key showed a small but consistent change with age, reaction by pressing a key gave irregular changes It thus seems possible that a more complex responding movement may in some way enable compensation to be made for slow reaction time

An experiment by Singleton (see Welford, 1958), however, has shown no difference of age change in reaction time with different complexities of movement His subjects' task was to move a lever from one end to the other of an 18 inch slot in response to a signal light. Each subject performed a number of trials in which he moved the lever in one direction only and others in which he moved it from one end to the other and back again The reaction times for the double movements were, as shown in Table 11 a little longer for each age group, but the differences were about the same for all ages

Conflicting evidence comes from an experiment by Griew (1959) in which subjects were required to move a stylus over a

or have a 3/16 inch hole into which the stylus had to be inserted The numbers of lights and of disks could be varied, providing different degrees of "choice" The experiment was carried out twice with independent groups of subjects In one, each signal was given separately following a warning In the other, a new signal appeared as soon as the stylus was returned to the starting disk. The times spent between the appearance of the signal light and the lifting of the stylus initiating the responding movement are set out in Table 12 For the younger subjects they show no regular increase when the more complex movement of inserting the stylus into the small hole was required The older sub-

dition The extra time seems to have been a constant absolute addition to that required for the simpler movement, whatever

TABLE 10*

SERIAL-REACTION TIMES AND MOVEMENT TIMES AS FUNCTIONS OF DELAY IN THE APPEARANCE OF SIGNALS
(Means per Response [in Seconds])

	Amount of Delay		
	0 0	0 1	0 2
Reaction time (i e center time minus delay)			
Younger (18–33)	0 335	0 298	0 307
Older (58–71)	412	362	356
Outward movement time			
Younger	085	075	068
Older	136	128	125
Time at end point plus return movement time			
Younger	258	243	234
Older	0 408	0 391	0 340

* From an experiment by Jeeves (see Welford, 1958)

the degree of choice The movement times between leaving the starting disk and touching the indicated disk were remarkably uniform throughout the two experiments These are also shown in Table 12

The conflict between Griew's and Singleton's results may perhaps be resolved if we again assume that older people find it difficult to overlap the planning of a movement with the execution of a previous one In Griew's case the movements were so short that they could be laid down in advance, and any extra time required by older people would be shown in the initiation time In Singleton's case it might well have been that older subjects did not really respond with double movements in the same sense as did younger They could, for example, have responded initially with a single movement and then, having made this, initiate the movement back again There was some evidence that this was happening in the fact that older subjects spent longer than younger between completing their movement in one direction and starting the return movement

TABLE 11*

REACTION TIMES PRECEDING SINGLE AND DOUBLE MOVEMENTS

(Means per Reaction [in Seconds])

	Age Range				
	Twenties	Thirties	Forties	Fifties	Sixties
Reaction times preceding					
Single movements	0 226	0 247	0 258	0 292	0 288
Double movements	0 237	0 265	0 279	0 298	0 299
Differences (D−S)	0 011	0 018	0 021	0 006	0 011

* From experiment by Singleton (see Welford 1958)

IV Speed and Accuracy of Movements

We may include under this head two classes of performance First, the making of simple repetitive movements and, second, tasks where more complex sensorimotor co ordination is required In the former it seems possible, in a sense, to lay down a single "program" of action which can then be run off more or less "automatically" without detailed attention In the latter the pattern of movement varies from moment to moment according to the dictates of the display The subject is thus not able to lay down a single program but must make a wider variety of movements and order these step by step in accordance with what he sees

Simple Movements

The factors limiting the speed of simple hand movements have been discussed in several papers since Woodworth's classical study (1899) Recently, a formulation has been made in information theory terms by Fitts (1954) in which he conceives the limiting factors as being the central mechanisms which guide movements He regards the subject's task when making a movement to a defined target as being akin to a choice reaction task The subject has, as it were, to select the target area out of a distance between the starting point and a point twice as far as the center of the target at which he is aiming (The doubling of the distance is largely empirical, and other slightly different formulations are possible, and in some ways preferable, without destroying the basic principle)

Fitts's formula for the time of these movements may be expressed thus

$$T_M = K\left(\log \frac{2A}{W}\right), \qquad (1)$$

where T_M = time per movement, A = amplitude of movement, W = the target width, and K is a constant If T_M is expressed in seconds, and logarithms to base 2 are used, the transmission rate in bits per second can easily be calculated

It is evident from Fitts's results that the actual central mechanism involved in setting the times for simple movements is different from that studied by Hick and by Crossman as setting the limit for choice reaction times Fitts obtained rates of information transmission about double those obtained by Hick It would appear, in fact, that the straightforward guidance of movement, although it may in some circumstances limit speed of performance, does not do so as severely as the translation from signal to responding action

Crossman in a personal communication has pointed out that a more fundamental statement of the principle underlying equation (1) would be

$$T_M = a + b\left(\log \frac{x}{\sigma_x}\right), \qquad (2)$$

where x is the mean amplitude of movement and σ_x is the standard deviation of the individual movements from this mean

TABLE 12*

INITIATION AND MOVEMENT TIMES FOR DIFFERENT COMPLEXITIES OF MOVEMENT AND DEGREES OF CHOICE
(Means per Response (in Seconds))

AGE GROUP†	SIZE OF TARGET (IN INCHES)	DEGREE OF CHOICE					
		Discontinuous Task			Continuous Task		
		2	4	8	2	4	8
		Time from Appearance of Signal to Leaving Starting Disk (i e Initiation Time)					
20–26	1¼ 1/16	0 37 0 38	0 45 0 44	0 52 0 54	0 36 0 41	0 46 0 47	0 54 0 52
Difference		0 01	−0 01	0 02	0 05	0 01	−0 02
0–57	1¼ 1/16	0 37 0 41	0 46 0 50	0 57 0 62	0 38 0 45	0 48 0 54	0 56 0 62
Difference		0 04	0 04	0 05	0 07	0 06	0 06
		Time from Leaving Starting Disk to Touching Indicated Disk (i e Movement ' Time)					
20–26	1¼ 1/16	0 20 21	0 19 19	0 20 20	0 23 20	0 20 19	0 21 22
50–57	1¼ 1/16	23 0 20	23 0 24	21 0 23	22 0 23	24 0 21	21 0 24

* From Grew (1958a)
† There were 12 subjects in each age group for each task i.e 48 in all

The type of formulation in equation (1) can be derived from this if x is assumed to correspond to A and if W is taken to be expressible in terms of σ_x If the scatter of movement amplitudes is large, the subject can be thought of as using a relatively wide target if the scatter is small, he is effectively using a narrow one

As regards studies of aging, two questions may be raised (*a*) do these central processes controlling movement limit speed of performance in older people in the same way as they do in younger, and (*b*) can the slowing among older people be conceived as a lowering of the rate of information transfer—in other words, is it proportional over various amplitudes and target sizes and therefore expressible as an increase of K in equation (1) or of b in equation (2)?

a) In answer to the first question we may note the results of two further experiments by Singleton (1955) In the first, the subjects were required to move a lever from side to side in a slot over a distance of about 18 inches They moved it back and forth as quickly as possible several times, and the time taken over various parts of the travel were recorded separately These times are given in Figure 11 and show that the older subjects were somewhat slower than younger but that slowness was confined to time spent at the end points, where the movement changed direction, and to the middle half of the travel The time [illegible] slot acts as a guide, and it can thus be thought of as a near approach to a "pure" motor action Comparing it with Single

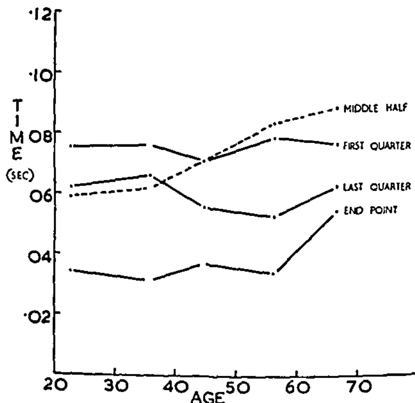


FIG 11 —Times for different stages in the movement of a lever from side to side in a slot (After Singleton, 1955)

ton's previous results, it would seem as if some genuine slowing with age occurs in movements of this extent although not in movements substantially shorter The fact that the slowing was not great is in line with Galton's results for the measurement he termed "swiftness of blow" This decreased from about 18 feet per second at age 25 to about 15 feet per second at age 65 in his sample—a fall of only 17 per cent (Ruger and Stoessiger, 1927)

limitation than are the actual muscular movements and that, when accurate aiming is needed, any slowing with age in the making of actual movements as such will be masked by slowing of the control of movement

b) Evidence relating to the second question is contained in an experiment by N Welford in which subjects had to dot from side to side between two targets either 1 inch or 2 inches in diameter and either

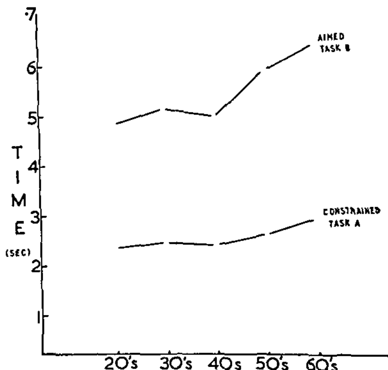


Fig 12—Times for two types of repetitive movement *A*, moving lever in slot, *B*, tapping with stylus between targets (After Singleton 1955)

The total times for this task are shown in Figure 12 and are there compared with the times taken for dotting with a stylus backward and forward over the same distance between two targets 1 inch in diameter It can be seen that the times taken by the latter task are at all ages much greater and that the rise with age is somewhat steeper It seems clear, therefore, that the central processes of guiding the hand to a small target are a more serious source of

1 foot or 2 feet between centers The times taken are shown in Table 13, together with the rates of information transfer calculated according to Fitts's formula. The rate for subjects in their twenties was similar to that found by Fitts, and it will be noted that this formula gives satisfactory results in the sense that the information rates for both target sizes and both amplitudes of movement are about the same The rate declined substantially with age until in the

sixties it was little more than half that in the twenties Again the decline was similar for both targets and both amplitudes of movement

The slowing could not have been due to a factor such as hand tremor increasing with age Any such tremor would add a small variance to the other sources of error so that equation (2) would become

$$T_M = a + b\left(\log \frac{\bar{x}}{\sqrt{\sigma_x^2 + \sigma_t^2}}\right), \quad (3)$$

where σ_t^2 is the variance due to tremor. This additional variance would reduce the effective target size for older people by an amount which would be relatively large for small targets and relatively small for large ones. It should thus have lowered the speed of performance by older subjects with the small targets much more than with the large. It can be seen from Table 13 that this did not occur. The slowing with age was about equal for both target sizes and seems better accounted for by an increase with age of the constant b than by an increase of σ_t.

TABLE 13*

SPEED OF "DOTTING" BETWEEN TWO TARGETS AS A FUNCTION OF TARGET SIZE AND DISTANCE
(In Seconds)

Age Group	1 Foot Movements		2-Foot Movements	
	2 Inch Targets	1 Inch Targets	2 Inch Targets	1 Inch Targets
	Mean Time per Movement, Including Time Spent on Target			
Twenties	0 293	0 370	0 401	0 491
Thirties	355	435	443	547
Forties	455	544	568	656
Sixties	*0 558*	*0 661*	*0 716*	*0 798*
	Rate of Information Transfer in Bits per Second			
Twenties	12 2	12 4	11 4	11 4
Thirties	10 1	10 5	10 3	10 2
Forties	7 9	8 4	8 1	8 5
Sixties . . .	6 4	6 9	6 4	7.0

* From experiment by N Welford (see Welford, 1958)

SIMPLE MOVEMENTS CARRIED OUT AT LESS THAN MAXIMUM SPEED

The studies reviewed so far have almost all been of tasks carried out as fast as possible consistent with accuracy. It is a relevant question to ask whether the fall with age noted in the maximum speeds is reflected in a fall in what are regarded as "comfortable" speeds of action. Four tasks included in a larger battery by Fieandt *et al.* (1956) provide some answer to this [illegible] ing from the wrist, (b) tapping with the ball of the foot on the floor while standing on the other foot and supporting himself by holding the edge of a table; (c) clap-

ping the hands in a rhythm alternately on the knees and twice in the air in front, and (*d*) "walking in a natural way the subject had to convey three matchboxes, one at a time, from one table to another The dis tance between the tables was 2 25 metres"

The results of these tasks are given in Table 14 All show some slowing in the eighties but very little before that age ex cept, perhaps, the walking task It is unfor tunate that no control data were taken of the same performances carried out as fast as possible, but, as the main purpose of the study was not to make such a comparison, the omission is not a matter of criticism

speed is relatively independent of maximum speed until a late age is reached

More Complex Movements

Experiments in which complex sensori motor co ordination has been required have shown very much greater changes with age than most of those we have surveyed so far The magnitude of the change that can occur is well shown in the results of an ex periment by Birren and Botwinick (1951*a*) on writing speed They required their sub-jects to copy digits and words, each ar ranged at random, for periods of up to 2

TABLE 14*

Times Taken To Make Movements at Less than Maximum Speed (In Seconds)

Task	Age Group							
	11 14	21 24	29 36	39 47	49–56	59 67	69 79	80 88
Tapping with forefinger (time to make 25 taps)	14 9	13 6	13 6	14 5	13 9	15 0	14 6	24 9
Tapping with foot (time to make 25 taps)	15 8	13 5	16 4	14 0	15 3	17 1	14 7	21 5
Clapping (time to complete 10 cycles)	16 9	14 6	16 5	16 1	17 8	17 9	16 9	24 1
Walking (time to complete the task)	13 4	14 0	13 7	14 0	14 0	14 8	17 0	23 5

* From Fieandt *et al* (1956)

Some control is given by the reaction times which are shown in Table 2 These were measured by pressing a button in response to a light given 4 seconds after a ready sig nal They show a small though fairly con sistent trend with age until the seventies when it becomes more pronounced The trend is similar to that found by Miles, shown in Figure 1 and by others shown in Table 2 Had preferred speed been related closely to maximum speed among Fieandt's subjects, we might have expected that his tests would have shown age trends similar to those of Miles s 'motility measures" shown in Figure 6 The fact that the trends are less marked than would be expected on this basis is an indication that preferred

minutes as fast as possible compatible with legibility Their results are shown in Fig ure 13, from which it is evident that there was a profound slowing after the thirties

The actual change of speed is not easy to interpret, since it is difficult to assess quality of writing accurately, and, without doing so, we cannot say how far younger subjects have sacrificed quality to speed Indications of speed and accuracy together were obtained in a figure tracing experi-ment by Brown (see Welford, 1958) The subjects traced with a stylus over brass fig-ures inlaid into an aluminum plate as

sounded when each figure had been traced completely and a buzzer if the stylus went over the edge The subjects traced first over figures the normal way round, then over another set each of which was reversed from left to right, and then again over the normal figures The times taken are given in Figure 14, and the numbers of errors made are set out in Table 15 Taking these two together, it can be seen that the thirties maintained speed at the expense of accuracy, but from the forties onward accuracy was restored at the expense of speed Before beginning the experiment the subjects wrote the figures 1–0 once on paper the normal way round, and before and after tracing the reversed figures they wrote them reversed The times taken for these three subsidiary tasks are shown in Table 16 It can be seen that the slowing for writ-

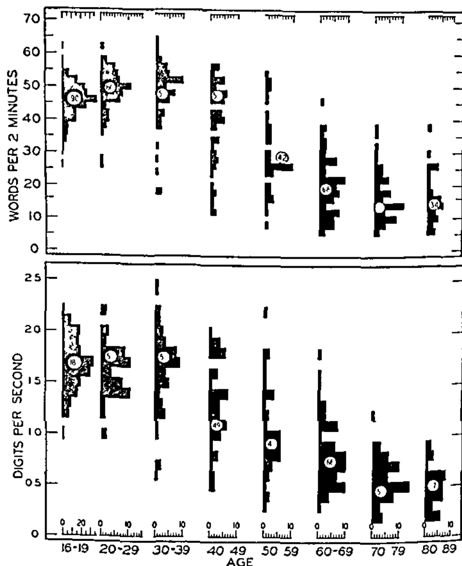


Fig 13 —Age differences in writing speed. Frequency polygons are shown for each age group The total number of subjects in each age group is indicated on the individual distributions the number of individuals in a single interval may be estimated from the frequency scales on the abscissa (After Birren and Botwinick, 1957*a*)

ing normal way round was of the same order as that found by Birren and Botwinick *and that the age changes for reversed writing were even greater* We shall return to this point later

TRACKING PERFORMANCE

A type of continuous performance task which received a great deal of attention during and shortly after the war was that of tracking a moving ' target " A series of experiments on tracking in relation to age have shown that performance at this kind of task changes a great deal with age at high speeds of target movement although very little at low speeds (Welford, 1958) In the first of these experiments the subject had to keep a pointer, which he could move by means of a handle on the side of the apparatus, *in line with a target moved* to and fro irregularly by a cam In two further experiments the subject was required to ' drive" a ballpoint pen along a track on paper drawn downward past a window his control was a steering wheel, and the apparatus was arranged in such a manner that more or less of the track could be seen ahead of the pen The course of the target or the track could in all cases be conceived as that of an approximate sine wave with irregularities or harmonics

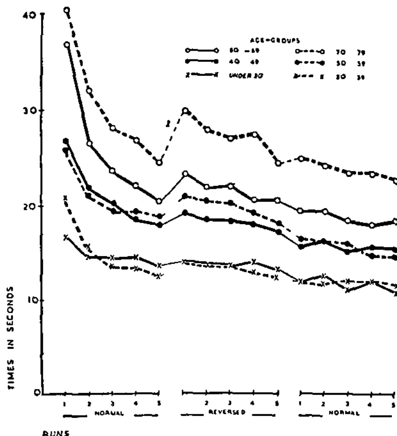


FIG 14 —Times taken to trace ten figures (1–0) (After an experiment by Brown [see Welford, 1958])

At low speeds the subjects could track in *step with the target*, but, as the speed was raised, they began to lag farther and farther behind, and their "swings" became

progressively shorter The shortening of the swing appeared to occur when the subject was so late that he was swinging out of phase with the target by more than 90° It was of such a nature that the amount of movement he made per minute remained approximately constant although this meant that, as the excursions of the target rose in frequency the subject's own movements became individually smaller Results for the first experiment are shown in Fig

TABLE 15*

ERRORS MADE IN TRACING TEN FIGURES FIFTEEN TIMES

Age Range	Mean Errors per Subject
Twenties	20 5
Thirties	54 3
Forties	29 7
Fifties	8 8
Sixties	17 4
Seventies	7 3

* From an exper ment by Brown (see Welford, 1958)

ure 15 and Table 17 In this the subject could not have any idea of what course the target was going to pursue In the other experiments, where his preview of the track could be varied, it was found that performance rose up to a point as preview was increased but that, however much was given, the age groups did not attain equal performances The amounts of movement and of time lag in relation to amounts of preview are shown in Figure 16

At first sight these results seem to permit three possible explanations First, that the older subjects were more cautious than the younger second that they were unable to swing sufficiently fast because they could not make the necessary movements in the time allowed, and, third, that the experiment was measuring a rather fundamental capacity to transmit information from the track to the control and that this capacity falls with age The first of these explanations seems to be excluded because, although it might reasonably apply where preview was not given, it could hardly be the explanation where the track could be seen well ahead unless some other limitation was operating also If the subject can see the track far enough ahead, he should have plenty of time to prepare his actions as carefully as he wishes unless other factors are limiting the extent to which he can usefully look ahead This, as we shall see, seems likely to be the case The second possibility was shown by control experiments to be unimportant and is obviously so when preview is excluded, because the amounts of movement made with long preview are so much greater Some limitation upon capacity seems therefore to be implied

The capacity concerned seems to be of two different kinds first, the *rate of transmission* and second, the *storage of information* Both these may need a little explanation The first means that, as we have already seen, the observation of a display and the shaping of accurate movements in response to it take time and that only a certain amount of such "work' can be done in any given amount of time As the track is speeded up, this limit is gradually reached and then passed When this happens, some breakdown of accuracy will occur The shorter swings made by the subject in response to the excursions of the target appear to represent a lessening of the differentiation between one responding movement and another In this way the

TABLE 16*

TIME TAKEN PER SUBJECT TO WRITE TEN FIGURES (1–0) ONCE
(In Seconds)

Age Range	Normal Way Round	Reversed First Time	Reversed Second T me
20–29	7 3	21 3	12 4
30–39	7 7	20 3	14 5
40–49	9 3	33 8	20 9
50–59	7 7	31 9	22 8
60–69	11 7	34 9	25 1
70–79	12 5	55 5	37 2

* From an experiment by Brown (see Welford 1958)

amount of information transmitted from display to control is reduced, and the time taken per swing is shortened The subject is thus able to continue to make the correct number of swings, although at some sacrifice of accuracy Adequate preview of the track may enable him to avoid tracking late and so keep his swings in time with the excursions of the target, but it cannot overcome the limits of his capacity to transmit information The amount of preview which can usefully be given is thus limited in amount

TABLE 17*

MEAN TIME AND PHASE LAGS IN A TRACKING EXPERIMENT

	Speed in Mean Seconds per Swing of Target				
	1 6	0 9	0 6	0 47	0 4
Subjects under 30					
Time lag (seconds)	0 10	0 15	0 24	0 30	0 30
Phase lag (degrees)	11	31	73	118	134
Subjects over 30					
Time lag (seconds)	0 24	0 28	0 31	0 30	0 29
Phase lag (degrees)	27	55	94	120	129

* From Welford (1958)

Even where the limit of capacity to transmit information is not reached, the amount of preview likely to be used is limited by the fact that any information seen ahead has to be stored in a kind of running short term memory until it can be used The capacity of this short term memory seems to become lower with age Evidence for this is contained in an experiment by Griew (1958*a*) using the same apparatus He gave preview of the track for a substantial way ahead, but obscured the portion just ahead of the pen, thus forcing the subject to store data over a brief period Under these conditions older subjects were at a relatively severe disadvantage Griew's results are shown in Figure 17

What is perhaps more direct evidence on the lowering with age of the capacity for running short term memory comes from an experiment by Kirchner (see Welford, 1958) following a preliminary experiment by Kay (1953) The subject was confronted by a box containing a row of twelve Morse keys each with a light above it The lights came on in random order at 2 second intervals The subject's first task was to press the key under each light as it appeared This was found easy by both younger and older subjects The conditions were then changed so that the subject had to press the key under the light which had just gone out—in other words, to work "one back" in the series This task proved easy for the younger subjects, but the

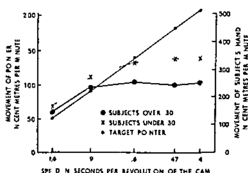


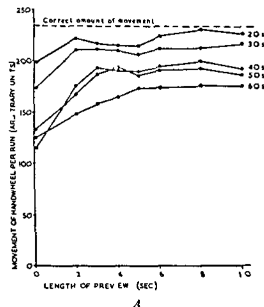
FIG 15—Average distances moved by subject's pointer and hand in a tracking experiment (After Welford, 1958)

older showed some signs of difficulty and made some errors The conditions were then changed so that the subjects had to work "two back" in the series This condition proved a little more difficult for the younger subjects and quite impossible for many of the older As Table 18 shows, even those

older subjects who were able to attempt the "two back" task made only a third of the possible number of correct responses

INTERRUPTION OF TRACKING PERFORMANCE

A further tracking experiment by Griew (1958*b*) has taken up the question of whether the interfering effect of additional signals to which responses have to be made increases with age His subjects were required to respond by pressing a key as quickly as possible to the sound of a buzzer given at irregular intervals while they were tracking. He found that tracking performance was about equally impaired by the distracting task in two groups of ten subjects aged 24–31 and 42–50 The two groups showed very similar reaction times to the buzzer given apart from the tracking



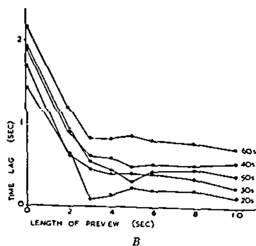
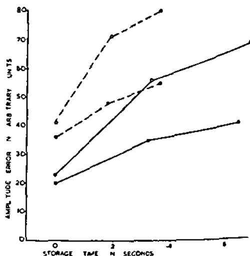


FIG 16 —Tracking performance as a function of preview of the track *A*, amount of movement of subject s pointer, *B*, time lag (After Welford, 1958)



at speed of 0 34 second per swing The storage time plotted on the abscissa is the time taken by any point on the track to travel under the mask, less any

1958*b*)

task It seemed as if the performance at the double task could be adequately accounted for in terms of performance at the tracking and the reaction time tasks separately and that there was no additional handicap to the older subjects from combining them

V Effects of the Relationships between "Display" and Responding Action

We have noted before that all sensorimotor performance involves translation from perception to action and that some cases appear to be simple and direct but that others involve more or less elaborate intermediate steps which may cause difficulty. These effects have been studied among young subjects by many authors and have been shown to be substantial. We shall here survey several experiments in which such 'translation' processes have been studied in relation to age. They are in many ways akin to the translations involved in digit symbol and other substitution tasks and thus form a link between sensorimotor performance and the material of other chapters.

Several of these studies have been concerned with mirror effects, for example, those of Snoddy (1926) on mirror tracing and of Ruch (1934) using a pursuit rotor. The results obtained by the latter author are given in Table 19, from which it will be seen that the relative fall of performance with age when the target could be seen only in a mirror was greater than when direct vision was possible.

Similar results analyzed in somewhat greater detail have been obtained by Szafran (1953, see also Welford, 1958) for throwing at a target. The task was presented under three different conditions: (*a*) throwing directly at the target, (*b*) throwing over a bar, which slightly complicated the motor task, and (*c*) throwing over a screen of the same height as the bar which hid the target from view so that it could be seen only via a mirror close behind it. Szafran found that performances from the late teens to the fifties were not significantly different in the first two tasks but that there was a rise with age of the errors in the third condition in terms of throwing too far or too near. This was accompanied by a number of other changes of performance, for example, some slowing and a tendency to "rigidity" in the sense of making insufficient correction for errors.

Snoddy attributed the lower performance of older people in mirror tasks to their being slower at learning the required new co-ordination, while Ruch regarded the mirror as introducing a conflict with previous habits. Both these factors doubtless play a part but would seem to miss the core of the problem. The subject is required in a mirror task to, as it were, "turn the display round mentally," or to employ some rule of procedure. The mirror does, in short, require that some additional stage or process be inserted in the translation from dis

TABLE 18*

Percentages of Correct Responses in a Serial Short Term Retention Task

	No. of Items Back in the Series Subjects Were Required To Work			
	0	1	2	3
Younger subjects aged 18–25				
Students	100	99	93	73
Naval ratings	100	99	81	51
Older subjects aged 64–78	99	80	33	N a †
Older as proportion of younger	99	81	38	

* From an experiment by Kirchner (see Welford 1958)
† Not attempted

of the bulbs was on, and the subject's task was to press the key corresponding to it, whereupon the bulb would go out and another light up, and so on through a series in which the various bulbs lit in random order In one experiment (Kay 1955) performances were compared (*a*) with the lights immediately above the keys, (*b*) with the lights 3 feet away across a table, and (*c*) with the lights 3 feet away and the box turned through 180° The results are set out in Table 22 and show that there was little change with age in (*a*), that in (*b*) the oldest subjects were slower but slightly more accurate, and that in (*c*) there was some rather more severe slowing among the oldest subjects

TABLE 22*

TIMES AND ERRORS AT A SPATIAL TRANSPOSITION TASK

(Means per Subject per Run of 30 Responses)

Age Range	Condition a	Condition b	Condition c
	Times (in Seconds)		
15–24	22 8	38 4	75 9
25 34	23 9	37 7	86 5
35–44	23 4	38 6	76 6
45–54	24 3	37 6	85 9
55–64	25 5	44 8	92 9
65–72	26 9	47 5	126 7
	Errors		
15–24	0	5 5	9 1
25–34	0	4 2	10 1
35–44	0	3 9	8 3
45–54	0	4 5	10 6
55–64	0	3 5	7 8
65–72	0	2 4	8 2

* From Kay (1955)

The age changes were small, however, compared with those in a second experiment by Kay (1954) in which a more complicated translation was required between lights and keys In addition to the two boxes there was a card with the numbers 1–12 on it in random order The lights were placed 3 feet from the keys, and the card was placed in one of three positions in different trials (1) by the keys, (2) halfway between the lights and the keys, and (3) by the lights Conditions (1) and (2) are shown on the left and right, respectively, of Figure 18

The subject was told

(i) Think of the lights as being numbered 1–12
(ii) When the light goes on, decide which number it is
(iii) Find the number on the card
(iv) The correct key to hit is the key in line with the number on the card

Two examples of lights and their corresponding keys are shown in Figure 18

Although the instructions applied equally to all three conditions, these varied greatly in difficulty, as can be seen from Table 23 It appeared that the rise with age of time taken and of errors was moderate in condition (1) and was moderate also with the increase of difficulty from condition (1) to condition (3) among the youngest group When, however, age and difficulty were combined, the rises were very great The disproportionate effects of difficulty as age increased are strikingly shown in Figure 19

The immediate cause of the difficulty seemed to be that in condition (3), and to a lesser extent in condition (2), older subjects tended to avoid the double task of both using the card and aligning across the 3 foot gap between the lights and the keys They did this by methods which led to two recognizable types of errors One type resulted when they imagined the *keys* to be numbered and pressed the key corresponding to the number on the card opposite the light which was on The other type occurred when they pressed the key immediately opposite the light, either because they omitted to use the card at all or because they used it twice by finding the number corresponding to the light and then

pressing the *corresponding numbered* key instead of the key opposite the number on the card

The basic cause of the difficulty for older people at this task is not indicated definitely by the results, but it is tempting to compare Figure 19 with a classical one of Lashley's showing the relationship among performance, difficulty, and brain injury If for 'amount of brain tissue removed" we substitute "age,' the resemblance is very close The drawing of such a parallel is perhaps plausible in that one of the characteristic changes with age is the reduction in the number of active brain cells (Appel and Appel 1942)

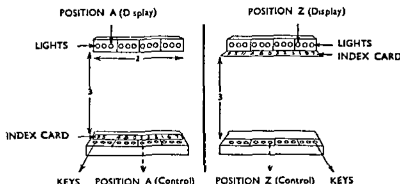


FIG 18 Layout of apparatus in an experiment by Kay (1954) combining spatial transposition with symbolic translation

TABLE 23

TIMES AND ERRORS IN KAY'S (1954) EXPERIMENT

(Means per Subject per Run of 20 Responses)

AGE RANGE	CONDITION 1	2	3
	Times (in Seconds)		
15 24	56 4	70 8	84 8
25–34	54 2	71 7	111 6
35–44	62 0	85 7	137 1
45–54	54 1	96 3	174 7
55–64	73 7	124 8	229 3
65 72	84 7	198 7	445 3
	Total Errors		
15–24	1 2	2 9	4 0
25–34	1 3	3 2	8 5
35–44	2 6	4 5	13 6
45 54	2 6	8 5	23 5
55–64	3 6	7 3	33 6
65 72	3 1	15 0	47 9

VI ORGANIZATION OF COMPLEX PERFORMANCE

We have already seen two factors which are likely to disturb the smooth flow of continuous performance in older people, namely the difficulty of overlapping the organization of one action with the execution of a previous action and irregularity of timing The first would obviously tend to make performance jerky and lead to its being executed piecemeal The second would have much the same effect for a different reason when the time taken is variable it is impossible to plan actions ahead with the same degree of certainty regarding their outcome, so that it becomes necessary to wait to observe the results of one action before deciding upon the next The same would result from any impairment of the accuracy of performance, but in this case it appears that older people are often able to compensate by taking more time Another facet of compensation in these circumstances may well be the tendency noted

by Szafran (1955) for older people to look more closely and more continuously than younger at what they are doing

The fact that such compensation occurs at all implies that individual detailed actions are welded into larger units, and its continuation at later ages implies that these larger organizations are not severely, if at all, impaired with age Some evidence in support of this view is contained in the results of Jeeves s experiment already mentioned, where the introduction of delays between the completion of one response and the occurrence of the signal for the next in a serial reaction task resulted in all components of the performance being affected, both among older subjects and among younger

Two further pieces of evidence may be quoted, one is an ancillary finding in N Welford s experiment already outlined. The subjects performed a subsidiary task in which they had to dot back and forth between two targets of different sizes As was expected, results were intermediate between those obtained for dotting between two small targets and two large ones What was not expected, however, was that this averaging applied not only to the over all results but also to the individual movement times and times spent on the targets Thus, for example, movement from a small target to a large one was slower than from a large target to another large one, while movement from a large target to a small was faster than from one small target to another Clearly, the task as a whole was exerting some influence upon the individual parts The results are shown in Table 24, from which it can be seen that, although the averaging effect was a little reduced in the sixties, it was still clearly present.

What is perhaps the fullest and most penetrating evidence concerning the organization of complex performance among older people comes from an experiment by Brown (see Welford, 1958) The subject sat in front of an apparatus on which were

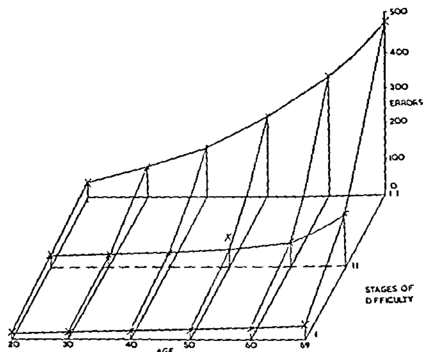


FIG 19 —Graphical representation of Kay s (1954) results relating performance to difficulty of task and age

two pieces of graph paper, size 6 × 4 inches. On one of these was a small steel ball. The subject's task was to plot the position of this ball on the other by means of a pointer carrying a small black spot. When the subject thought he had plotted correctly, he pressed a button on the handle of the pointer, and, if the position was correct, the ball started to move until it was stopped by pressing a key at the side of the apparatus. The subject then began to plot the new position of the ball, thus beginning the cycle of operations over again. In the record of errors, minor inaccuracies of plotting ("small errors") were separated from "large errors" which arose from attempting to use as reference lines the edges of the graph papers instead of the co-ordinates drawn upon them.

TABLE 24*

TIMES FOR DOTTING BETWEEN TWO TARGETS OF UNEQUAL SIZES COMPARED WITH THOSE FOR TWO EQUAL TARGETS†
(In Seconds)

Age Range	Moving to 2 Inch Target	Moving to 1 Inch Target	Difference between Last Two Columns	Difference between Moving over Same Distance between Two 2 Inch and Two 1 Inch Targets
	1 Foot Movements			
Twenties	0.344	0.341	−0.003	0.077
Thirties	.402	.418	.016	.080
Forties	.511	.526	.015	.089
Sixties	0.597	0.630	0.033	0.103
	2 Foot Movements			
Twenties	0.456	0.443	−0.013	0.090
Thirties	.517	.522	.005	.104
Forties	.622	.633	.011	.088
Sixties	0.739	0.800	0.061	0.082

* From an experiment by N. Welford (see Welford 1958).

† Each time is the sum of the time taken to move from one target to the other and of the time spent on the target from which the movement is made.

Observing the subjects, it was clear that the method adopted by the younger and older subjects tended to be very different. The young subjects acted rapidly, swinging the pointer into position and pressing the button almost immediately. If they had plotted accurately, this procedure was, of course, fast and economical. Often, however, the first attempt did not make the ball move and had to be followed by several other attempts leading to small errors before success was achieved. The older subjects were much more careful and meticulous. They tended to plot on the two dimensions separately, swinging the pointer first one way and then at right angles, and, when they had it in position, they usually checked, often counting the squares on the "grids," before making any attempt to start the ball. The differing methods of the two age groups showed in the times taken between stopping the ball and making the first attempt to restart it. It can be seen from

production operations it was clear that among the variables they studied the most closely associated with age changes was demand for speed Operations tended to be staffed by younger people where there was pressure for speed either because of a high individual piecework incentive or because there was a rigid pacing imposed by the machinery with no chance of redeeming errors due to slowness and serious results if items were missed The difference in the age distributions of operatives on jobs possessing these characteristics as opposed to jobs where stress upon speed was less is shown in Figure 22 Belbin found that the most severe conditions obtained where demands were made both for speed and for continuous bodily movement as shown in Table 29

Richardson (1953) who in a study of coal miners and foundry workers showed that many changed to lighter work especially in the late fifties and early sixties suggested that some of the shifting was not to work making less severe physical demands but to work that could be done at the men s own pace It is of course difficult to be sure how far the ability to work at one s own pace is welcome because of a reduction in the demand for rapid sensorimotor co ordination and how far it means only that the worker is free to do less than he would otherwise and can therefore put forward less effort over a period of time even though the maximum required upon occasion may remain the same

Taking the evidence together it seems that both speed and physical effort enter into the definition of work suitable for older people but it is the former which commonly limits performance at the earlier age Where jobs are designed to be carried out to the limit of psychomotor or physical powers they seem commonly to be pitched at a level suitable for men in their middle or late thirties—an age at which industrial productivity seems often to reach a maximum Above this age men are able to carry on for a time in spite of failing powers but often under an increasing strain Eventually most of them leave for other work Age is seldom stated as a reason for leaving but often seems clearly enough to be the true cause Changes to work making lower demands for speed commonly occur in the early fifties while changes to less strenuous work appear to reach their peak some five to ten years later Because of this difference between the effects of the two types of demand a number of instances can be noted where men and women change in the early fifties from light fast work to jobs which are actually heavier in the sense of demanding more severe muscular effort

It should be noted that these various trends are often difficult to detect Individual performance seldom falls much with age as judged by productivity figures although Wackwitz (1946) has shown that steady small declines occur when substantial numbers are studied Age changes are much more likely to show in moves to different work although these moves are seldom attributed to age effects as such

Accidents

Several studies of industrial accident rates in relation to age have been sum

ity or both tend to rise It seems clear that the relationship between accidents and age varies according to circumstances It is presumably dependent upon the exact nature of the risks to which the people concerned are exposed and upon whether the older and the younger people included in the study are exposed to equal degrees of risk Even where people of different ages are doing nominally the same work small differences may substantially affect the risks they run

Studies which have included a detailed treatment of the nature and causes of accidents or have correlated accidents with other variables have shown that the accidents sustained by older people tend to be due to slowness in appreciating hazards or

in taking action to avoid them, whereas accidents occurring to younger people are often due to careless or foolhardy behavior Whitfield (1954), for example, in a study of coal miners found that the older accident prone men showed average or above-average performances at perceptual and cognitive tests but tended to do worse at tracking tasks Younger accident prone men tended to be heavy with powerful physique, to perform poorly on perceptual, memory, and cognitive tests, and to show reasonably adequate performance on tracking tasks Whitfield suggested that, as age advanced, the older men's performance gradually became slower to a point at

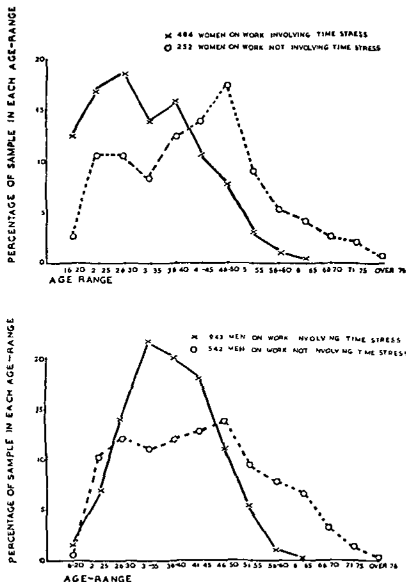


FIG 22 —Age distributions on operations with and without pressure for speed or rigid pacing *A*, men, *B*, women (From a study by Shooter and Belbin [see Welford, 1958])

which they could not deal rapidly enough with emergencies, while the intellectual failings of the young men combined with good physique and high levels of activity led them to take risks they failed to appreciate With age, however, their activity waned and they ceased to expose themselves to risk as much as they had formerly done

The results of a study by King (1955) of nearly two thousand accidents to agricultural workers are shown in Table 30 The total accident rate differed little with age, but the cause of accident varied greatly The increase of falls with age which King found is well known and was formerly thought to be associated with vertigo and other signs of vestibular impairment in old age Recent work (Sheldon, 1948, Droller, 1955) has indicated, however, that these falls are rather to be attributed to slowness of recovery once a person is thrown off balance King's third category of accidents which rose with age, namely, "Hit by falling or moving object," could also have been due to slower sensorimotor reactions in "getting out of the way"

TABLE 29*

RELATIONSHIP BETWEEN OPERATIONS FROM WHICH THERE WERE MOVES WITH AGE AND THOSE ON WHICH THERE WERE PACING OR A DEMAND FOR CONTINUOUS BODILY MOVEMENT AND ACTIVITY

	Moves with Age	No Moves with Age
Operations involving both pacing and continuous bodily movement and activity	10	1
Operations involving pacing without continuous bodily movement and activity	3	3
Operations involving continuous bodily movement and activity without pacing	6	7
Operations involving neither continuous bodily movement and activity nor pacing	0	77

* From Belbin (1953)

Of the causes of accident which declined with age in King's sample, "starting an engine" was almost certainly due to the fact that tractor-drivers tend to be young men (King, 1953) Avoidance of synovitis and other ailments due to "continued activity" and of becoming "caught in a machine" or suffering "injury inflicted by own tool" are probably the result of more careful experienced performance by older people King quotes figures from the same sample broken down in terms of "nature of injury" and "part of the body injured," and these reinforce the view put forward on the basis of his analysis of causes of injury

Effects of Mechanization

One of the most important practical problems regarding the employment of older people is that of designing equipment for industrial mechanization in such a way that it will be easy for them to use Mechanical equipment can drastically reduce the need for heavy physical effort and often removes, or greatly reduces, the need for fast manual manipulation Often, however, it introduces two factors which may cause substantial difficulty to older people First, hand processes which can be carried out at the operative's own speed are often replaced by operations at which the pace of work is determined by the machinery This pace is often slow enough, on average, to be well within the capacities of all except very old people If events requiring action by the operator can occur at random, however, these paced operations impose a continual risk of momentary "overloading," and at

and the more opportunity there would seem to be to take advantage of the steadiness and responsibility of attitude that older work people tend to possess

The second disadvantage for older peo-

ple on mechanized equipment is that it often destroys the directness of the relationship between what is seen and what is done and thus increases the intellectual demands of the job We have already seen that such indirect display-control relationships may be disproportionately difficult for older people The problem might often be minimized by the application of engineering psychology principles to the design of the equipment, and study of the performance of older people in relation to such points of design would seem to be especially worthwhile

TABLE 30*

CAUSES OF AGRICULTURAL ACCIDENTS

CAUSE	NO OF CASES	PERCENTAGES OF EACH KIND OF ACCIDENT BY AGE GROUPS					
		15 20	21 30	31 40	41 50	51 60	61 80
Significant increases with age							
Falls from heights or machines	252	7 6	8 4	10 5	14 5	19 2	16 4
Falls through slipping or tripping on ground	201	3 8	6 3	9 4	13 4	11 0	16 4
Hit by falling or moving object	339	14 0	15 7	13 9	17 6	21 4	21 3
Significant decreases with age							
Caught in machine	202	13 4	11 8	11 5	9 1	7 9	6 6
Injury inflicted by own tool	184	13 4	11 8	10 7	5 8	6 6	9 3
Continued activity	127	4 5	9 2	7 9	6 2	2 8	4 4
Starting an engine	98	12 7	7 9	4 1	4 5	1 3	1 1
No significant change with age							
Moving heavy objects	103	3 2	4 8	6 8	4 2	7 5	1 6
Knocked against or trod on object	90	6 4	3 6	5 3	4 9	3 4	3 8
Action of animals†	79	1 3	3 9	4 3	4 2	5 3	2 7
Trapped other than in machine	48	1 3	3 1	1 9	2 7	1 6	3 8
Miscellaneous	127	9 5	6 0	7 7	4 7	6 0	6 0
Cause not specified	141	8 9	7 5	6 0	8 2	6 0	6 6
Total	1991	100	100	100	100	100	100

* From King (1955)

† Some cases in which animals were involved were classified under Hit by falling or moving object This group constitutes the remainder

IX SUMMARY

Changes of performance with age have been considered in terms of recent research on human skill not specifically related to age This has shown clearly that sensorimotor performance involves a whole chain of mechanisms, both peripheral and central Limitations upon performance are commonly due to one only of this chain of mechanisms in any given set of circumstances, and the aim of research should be to identify which is setting limits in any particular task

Experiments relating performance to age have shown that, although peripheral organs may set limits in tasks requiring fine sensory discrimination or, at the other end of the chain, strenuous muscular activity, most sensorimotor performance among older people is limited by central mechanisms These may be conceived as having a finite capacity in the sense that there is a maximum amount that can be done at any one time and in any given period of time Compensation can to some extent be made for loss of capacity by taking a longer time,

and this appears to be a major cause of slowness of performance among older peo ple If this longer time is not taken accu racy appears to suffer and speed and accu racy can be shown to be in principle com pensatory

There seems to be relatively little change of speed or accuracy among older people with very simple tasks such as classical re action time measures Changes are greater when movements have to be carried out in a continuous co ordinated series They seem often to be very much greater still when complications are introduced into the rules by which the subject is required to relate what he perceives to what he does This is especially so when the time between the appearance of signals and the taking of responding action is such as to require the carrying of information over intervening activity it would appear that interference with short term retention by intervening activity is an important cause of difficulty for older people with certain types of rela [illegible] complicated task

ance For example older people display a rather consistent tendency when possible to shift their emphasis from speed to accu racy These changes could be viewed in many cases at least as being due to an ef fort albeit unconscious to make the best use of the capacities the subject possesses

The relation of age changes in sensori motor performance to other variables such as education and to the performance of other types of task is briefly surveyed

The industrial implications of the work outlined in this chapter appear to be that speed and complexity are often more seri ous sources of difficulty for older people than physical effort in jobs as at present constituted The effects of slowness and carefulness among older people are re flected in industrial accident rates It would seem that modification of the design of jobs to lessen requirements for rapid ac tion or the risks of sudden hazards and to lighten the intellectual load upon the oper ator could bring many jobs at present con fined to younger people into line with the capacities of those much older

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XVIII

Theories of Learning and Aging

HARRY KAY

I Introduction

To date the observed relations between learning theory and aging phenomena are tenuous This chapter is written from the standpoint that the connections have been weak that they could be strengthened and that it would be of value to both if they were In spite of frequent observations upon the dangers of forgetting that learning is an inference from performance the experimental pattern has been to measure an act and take too little notice of its antecedents or its consequences Yet aging studies force upon our attention that such an isolated measurement in time is of an act that is neither isolated nor unique Learning is part of a general biological development and is best understood in terms of what has gone before Though this is not to say anything new it is to say something which is too often forgotten

There is no widely accepted definition of learning and there is little point in adding another to the long list of unaccepted A biological organism has to adapt to changes in its environment such adaptation being achieved by a variety of neural mechanisms some reflex and some instinctive and that behavior which has not fallen under these designations has tended to be packaged under the label of learning This could provide us with a cumbersome definition by exclusion if only there were agreement upon the other two terms reflex and instinct but this is not so Beach (1951) in particular has quarreled with the definition of instinct and would prefer to discard it There is then a wide variety of so called learned behavior and as we ascend phylogenetically we increase the amount of behavior so designated

The complexity of the problem is increased when we consider the learning characteristics associated with age It will be apparent from chapter xix that the evidence upon the learning abilities of older subjects is not unequivocal There is no conclusion which has not been challenged with the possible exception that the data so far are inadequate to support any firm and general conclusion The most prevalent opinion has been that old subjects as compared with young do learn more slowly and that they are disproportionately handicapped when faced with novel or difficult material and by speeded or paced conditions A typical objection to this negative view is that it is based upon a narrow and unrepresentative range of tasks (Lorge 1956) A satisfactory explanation is not likely to be forthcoming where there is no agreement about what requires explanation Obviously a first step is to establish the necessary data but aging studies may be able to gain by working within the theoretical formulations adopted by other learning students and by examining whether their suggestions do or do not throw light upon aging phenomena Accordingly in this chapter it is proposed to look at both the ideas put forward by researchers in aging and at the proposals made by learning theorists which might be applicable to aging studies

Different Kinds of Learning

The evidence for learning has traditionally been the response. If the organism could deliver this end product, then it was a fair inference that it had learned. But it has long been acknowledged that this was an insensitive index, and measuring techniques such as the saving method (relearning), or the ability to recognize as opposed to recall items, were adopted in attempts to ascertain whether or not the organism had retained material. The fundamental problem which these or any other methods face as long as they are based upon some probability of response function is that learning is not only a complex but a multivarious process; they may be adequate enough measures of the end product but too often are inadequate of the various processes which go to make up learning. Failure at any one stage may lead to failure of performance, but, if, as in so many experiments, only the end response is being recorded, there may be little or no hint where the hiatus occurred.

Registration, Retention, and Recall

The series of stages which make up learning have been emphasized in its traditional three R's—registration, retention, and recall. Any one of these may easily be subdivided. For example, registration would include such stages as perceiving, assimilating, and, in certain instances, making some sort of abstraction of material. Such stages would involve interaction between what is already held and what is presented. They would also necessitate a form of storage, if only of a temporary kind. Psychological breakdowns of this kind may be paralleled by the neurologist who sees the first stages as inputs to the sensory projection areas, with interacting excitations spreading from the reticular formation and the lymbic system. Increasing knowledge is likely to see the introduction of more subdivisions, each arising from a new area of experimental attack (Welford, 1956).

An example of such an area of new interest would be the experiments around short term memory studies, this being a focus point for studies of skills and the operator's ability to handle various channels of information, for experiments upon simultaneous binaural stimulation, and for immediate memory studies where the subject is faced with varying degrees of interference. It would seem that not only will our *understanding of learning be advanced by* this intensive study of individual stages but that it should be of particular utility to aging studies by enabling the experimenter to examine how far older subjects are handicapped or facilitated at these points.

On the other hand, it has been one of the pleasing features of recent psychological thinking that the introduction of approaches and concepts from other disciplines has tended to integrate various fields which have traditionally been isolated from one another. An example was in the study of communications from which psychologists derived both the idea of feedback and the statistical advantages of information theory. These have been widely used in studies involving learning, perceiving, and thinking and are likely to be further developed in the future. The relevance for aging studies of linking these psychological processes to one another is that in the adult system learning has to take place where other processes are fully developed and organized. It is not known how much learning under these conditions differs from learning by an immature organism, but the probability is that it is radically different. The perception and the assimilation of material are known to differ, and it is probable that the storage and the ultimate selection of what is stored (recalled) are also affected. This is the material for this chapter, but it will be noticed at the outset that under the one name we are discussing not one process but many and not one kind of learning but several. With such diversity there is little wonder that learning situations are so different from one experiment to another and that the theory which is

adequate for one type of situation is inadequate for another Even where theorists have talked the same language, they have not always talked about the same thing We may now examine why

II Different Kinds of Learning Theory

Just as there is more than one kind of learning so there is more than one kind of learning theory purporting to explain this many sided process These theories are best understood in terms of their historical background in addition to the idiosyncrasies of their various authors In this section three main streams of influence will be distinguished—that from the philosophical tradition, from the biological sciences, and from mathematics and the physical sciences—and a brief indication given of the kinds of theory to which they gave rise

Influence of the Philosophical Tradition

The study of mental events had for long been the province of the philosopher The tradition can be traced clearly enough from Aristotle and reached a notable peak in Descartes's clear-cut dualism of mind and body Descartes's emphasis upon the mechanical operations of the body not only influenced the development of physiology but also directed scientific thinking within psychology itself It was however, the empiricist tradition in British philosophy, with its doctrine of associationism which was the immediate and most significant influence upon experimental psychology Associationism was a well established tradition when experimental psychology was beginning, and much of the early theorizing was either a continuation of or a reaction against it The obvious expression of this was in the enormous volume of work which was done upon conditioning and the central position which this played in behavior theory as put forward by Watson Such work covers the whole of the first four decades of this century, by which time newer theories, often derived from the old, were being put forward.

CONDITIONS INFLUENCING LEARNING

It was the aim of many of the early studies of learning to "explain" learning by examining the conditions which were necessary for it to take place Such studies enabled the psychologist to "predict" a wide variety of events, because he had previously observed the antecedent conditions which led to this behavior At this stage the theorist was working at the level of empirical generalizations On a similar basis he might satisfactorily have predicted the speed or breakdown of the railway engine but still have believed, with the Indian, there was a horse in the boiler It may well be argued that what is in the boiler is irrelevant, he is not trying to "feed the brute" but simply state whether the train will or will not get there on time This is fair enough Prediction is not synonymous with understanding, and with certain classes of phenomena, including human behav or mankind has long been satisfied

chologists differed from their fellows

INTERVENING VARIABLES IN BEHAVIOR THEORY

As experiments accumulated, efforts toward theory construction became more sophisticated The external events in the environment, such as the stimulus, the time and occasions of its presentation, were now related to the hypothetical variables which

cedent experimental conditions to which they were related Tolman (1938) proposed that these guesses should be named "intervening variables"

These abstract concepts are the core of behavior theory, and a great deal of sense and nonsense has been written about them

At a general level it is clear enough what is meant The theorist makes a guess at what intervenes between the stimulus conditions (the independent variables) and the responses (the dependent variables) Examples of intervening variables are Tolman's "demand," "appetite," and "sign Gestalt expectations", Hull s 'habit strength" and "*g*", and Skinner's "reserve" Such intervening variables are not restricted in their use to the one set of experimental conditions for which they may have been first conceived From the particular instance they may take on the general and more important function of being used in the formulation of the fundamental laws of behavior theories This is their significance to learning theory they have been its basic tool Experimentation and theory have been directed to specifying their exact relations to the "stimulus" and the "response," Hull in particular, attempting to express them in mathematical formulae and predict the course of future behavior on their basis

In trying to infer the intervening processes, many authors tended to blur the distinction between what were purely hypothetical ideas, on the one hand and tentative suggestions at neurophysiological entities, on the other This was no great crime and, insofar as any variable which has further properties outside the particularized situation is thereby open to further examination, it should not confuse But it might be noted that a rigorous distinction between intervening variables limiting them to intermediaries with no properties other than those specified in the immediate defining situations and hypothetical constructs which may have extraneous properties, generally physiological was proposed by MacCorquodale and Meehl (1948) and as vigorously opposed by Bergmann (1953) and Adams (1954) Our interest is not to arbitrate on the issue but to note that this hypothesizing of certain variables, whatever their defining characteristics, is central to much of one kind of learning theory

Influence of the Biological Sciences

It was not until the biological sciences had made their own advances and established themselves as independent disciplines that experimental psychology emerged To the learning theorist who is interested in the early work of, say, Galton (1883), Ebbinghaus (1885), and Thorndike (1898), the influence of these sciences may not be obvious, but more than anything else it was the application of physiology to the problems of the nervous system which so profoundly shaped early psychological thinking Physiologists had enjoyed notable successes from their discovery that sensory and motor nerves were functionally discrete (Bell and Magendie), to their concept of functional levels in the organization of the nervous system (Hughlings Jackson), and the impressive contributions of Helmholtz to perception and the study of nerve conduction In another field clinicians working with newly introduced techniques for fixing and staining sections of the nervous system, were optimistic that the unfolding details of neuro-anatomy would unfold the mechanisms subserving all brain functions The beginnings of psychology were then in a period of buoyant optimism in the biological sciences, and inevitably psychology was influenced by them This hopeful sentiment was not to last, and the efforts to identify the operation of particular neurological units met with no immediate success Even so, as the physiologist advanced his understanding of the over all working of the human and animal organisms particularly in the researches of Adrian, Lorente de No, and more recently Eccles (1953), it was necessary for the psychologist to assimilate the general implications of these findings The early studies, revealing the continuous electrical activity of the brain, made it appear improbable that behavior was completely controlled by sensory events, the more recent studies, revealing that the same stimulus may be transmitted to different areas

before and after conditioning demonstrate the differing roles which that stimulus may play This interchange of ideas between the two subjects shows every indication of increasing

THE USE OF PHYSIOLOGICAL CORRELATES

One use of physiological concepts has already been noted with the introduction of hypothetical constructs This raises the issue for the learning theorist of how far it is or is not necessary to tie observables to physiological correlates and of how far it is helpful or even convenient Many would be prepared to admit with Bergmann (1953) that "logically and in principle physiological reduction is a certainty Every bit of behavior and everything that can like conscious contents be defined in terms of behavior has its physiological correlates but they would also want to go along with him in supporting the logical soundness of a non physiologizing behavior theory We may briefly consider the advantages to be gained from using physiological constructs

When the elements in a system are given neural properties they will have to satisfy two criteria the known behavioral evidence and the possibly less fully known neurophysiological data The apparent vulnerability of such a system is attractive, but, since neurophysiological speculations are often difficult to examine the vulnerability is not so open as it might appear However it may be argued that in theory at least, such speculations may provide the neurologist with some hints about the elements in the system

Where the effort is made to tie theory to the known neurological evidence this may clip the wings of fancy, but its advantages are real enough, such an identification with a particular neurological change may give the theorist the clearest hint he is likely to receive about the operation of the system Again in practice few such identifications have been made in spite of notable work over many years by researchers such as Pavlov and Lashley It would seem that here was primarily a technical problem, ablation studies were not only painstaking in the extreme but, as the electrical engineer knows, the results from a mutilated system are open to an appalling number of interpretatons Thus initial work did not yield a big return Present successes employing newer techniques, notably microelectrode implantations, are the most promising sign in this area (see below, 'Influence of Subcortical Structures upon Learning")

Influence of the Physical Sciences and Mathematics

Unlike the two previous influences, the physical sciences and mathematics did not have a marked effect upon early theorizing in learning in spite of their influence upon psychophysics But their influences have grown steadily and are probably at their peak today Several factors have contributed to this As psychological theory became more sophisticated, it tended to emulate the theories from other sciences, not always asking itself whether their models would necessarily be suited for its own purposes Since mathematics and physics enjoyed enormous prestige, it was toward

led to the introduction of new concepts and procedures for analyzing and comparing situations For example certain mathematical procedures have been applied in conjunction with neurophysiological concepts, the most notable being the development of nerve net theory which began with the work of Rashevsky (1938) and has been continued by such workers as McCulloch and Pitts (1943) and Culbertson (1950), who showed how the operations of symbolic logic could be applied to the study of nerve net activity The psychologist has fought shy of nerve net theory, probably because of its technical mathematics, but has widely used that part of it which is

concerned with the science of communication and which is familiar through Wiener's (1948) cybernetics Concepts such as feedback from the communication engineer or his statistical tool of information analysis are now frequent in psychological speculations, particularly those of the 'black box' variety Such theories attempt to specify the input and output characteristics of their model but make no attempt to deduce the kind of hardware which goes to make up the box For this kind of theory *neurophysiology is unimportant* What matters is discovering the functional relations between what goes in and what comes out Equipped with this knowledge, the experimenter can state the capacity and working functions of his model and is content to leave it there

Having briefly observed three of the influences which have governed the development of theoretical ideas about learning we will now turn to some examples of learning theory and their relevance to aging studies

III Psychological Learning Theories and Their Implications for Aging Studies

Theories of learning have frequently been summarized notably by Hilgard (1956), by Spence (1951) and by Osgood (1953) In this section it is proposed to indicate one or two main issues, to note the kind of variables which have been put forward in the most elaborated of the theories —Hull's—and to consider the bearing of this kind of work upon aging research

The classification of learning theories is an arbitrary procedure It has become the convention to group them according to their emphasis upon their theoretical constructs, one favoring perceptual variables (sign significate) and the other modifications of "stimulus response connections The S S theorists are following the Gestalt tradition and conceive the principal change in learning to be due to a perceptual organization or reorganization The S-R theorists account for learning in terms of the connections which are established between the stimulus and response, making postulations such as associations, bonds, or habits

An equally reasonable grouping would be to classify the theories according as to how such modifications were thought to come about This would make a division into those which held reinforcement to be necessary for learning and those that did not It is perhaps fortunate that many of the S S theorists believe that reinforcement *is not essential for learning, while most of* the S-R theorists do, thereby maintaining themselves in the same groups

Hullian Theory

If we were to plot a family tree for the theories following S R hypotheses, we should find, on the one hand, their historical roots in associationism as this was experimentally examined by Bechtereff and Pavlov in their conditioning studies, and, on the other, in hedonism as it was formulated by Thorndike in the law of effect Both lines have been continued by modern theorists and have reached their most sophisticated expression in the work of Hull (1943, 1952) The *conditioning studies* have broadened into the work upon habit formation or habit strength, the *hedonistic principle*, into studies of reinforcement and drive reduction

In order to give some impression of the direction and extent of this work, we may note in a very summary fashion some of the variables which Hull has proposed, beginning with his concept of habit strength For Hull habit strength ($_{S}H_{R}$), defined as the tendency for a stimulus trace to evoke an associated response, increases as a positive growth function of the number of reinforced trials The next step is to link habit strength with drives (D) and reaction potential ($_{S}E_{R}$) The hypothetical construct drive (D) *is definable in terms of* the deprivation to a primary need of the organism, thus the amount of hunger drive *would be a function of the observable ante-*

cedent conditions usually the number of hours of food deprivation Hull assumes that the multiplicative interaction of habit strength and drive determines the strength of the response

$$_SE_R = D \times {_SH_R}$$

It will be observed that $_SE_R$ is not the response itself it is the inferred process closest to response evocation Without D there will be no reaction potential irrespective of the strength of habit

Upon this simple basic formula are then added further variables It is postulated that an increase in the intensity of the stimulus and in the incentive reinforcement will increase the reaction potential for any given level of habit strength The equation then reads

$$_SE_R = D \times V \times K \times {_SH_R}$$

where V = stimulus intensity dynamism and K = incentive reinforcement.

In order to meet the facts of extinction in conditioning studies with no reinforcement Hull adopts the view that inhibition itself produces a negative reaction potential which will compete with $_SE_R$ There are two kinds of inhibition whenever a response is made reactive inhibition (IR) is generated and this impedes the repetition of the same response by directly reducing reaction potential But any stimuli closely associated with inhibition of response become conditioned to this inhibition and thereby generate conditioned inhibition ($_SI_R$) Both IR and $_SI_R$ summate to reduce reaction potential

Hull had long been intrigued by the evidence for behavioral oscillation and in his final system this oscillation $_SO_R$ was incorporated into $_SE_R$ it is in fact the standard deviation of $_SE_R$ Finally for a response to occur its reaction threshold ($_SL_R$) must be above the absolute zero (Z) of the momentary reaction potential

Hilgard has neatly summarized the above variables in Figure 1 The input variables in column 1 are defined by the directly measurable experimental conditions with the exception of $_SH_R$ Column 2 gives the intervening variables related to these conditions and whose interaction produces the intermediate step in column 3 and the net reaction potential of column 4 But reaction potential may be further varied by oscillation ($_SO_R$), and if a response is to occur the reaction potential must be above the threshold of response ($_SL_R$) The response itself may be measured by its latency ($_St_R$) its amplitude (A), or the number of evocations before extinction under non reinforced conditions (n)

As Hilgard points out the diagram falls short in not listing any of the stimulus components making up the complex of traces which are present when a stimulus is evoked These would include the drive stimulus (S_D) and the fractional antedating goal stimulus (S_G) But there is sufficient detail in the outline to indicate the kind of theory which Hull has put forward and the general level of its development.

AGING AND BEHAVIOR THEORY

Let us now suppose that the psychologist interested in aging attempts to use Hullian concepts in a *learning experiment* with animals Age enters as one of the independent variables In addition to producing the normal learning curves for two different age groups the experimenter attempts to manipulate the variables which Hull has indicated as controlling learning Are such variables differentially influenced by age? For example is habit strength built up at a different rate between different age groups when reinforcement is held constant? What is the rate of buildup of inhibition and is this sufficient to produce differences in extinction rates? This kind of experiment faces difficulties such as whether the drive (D) on the basis of *hours of deprivation* can be said to be constant when the comparison is between animals of different ages But it may enable the experimenter to state more exactly the differences in learning between his age

groups, that is, he may be able not only to state that they differed but to show how, by the manipulation of his variables, they differed One point stands out clearly The experimenters in aging will have to use much more controlled conditions than have generally been used Before any variables can be manipulated, it will be necessary to show that, when the variables are held constant, results are reproducible and that any observed changes are due to the prescribed alterations This would be to the good, since learning experiments with animals in aging studies have rarely had the rigor and continuity of attack that has been devoted to them in other spheres

Of course, whether a gerontologist follows such a line of research will depend upon his evaluation of Hullian theory It may seem to some that it would be sufficient to exercise a rigorous control on conditions, such that behavior could be predicted, but not to attempt a theoretical formulation over and above the prediction This would be more in line with Skinner's position Certainly, the control and reproducibility of results with Skinnerian techniques should be encouraging to students of aging and more their desiderata than hitherto

Theories Stressing Perceptual Factors

In contrast to the stimulus response type of theory, another group of psychologists have followed the Gestalt approach and conceived of learning as being primarily a

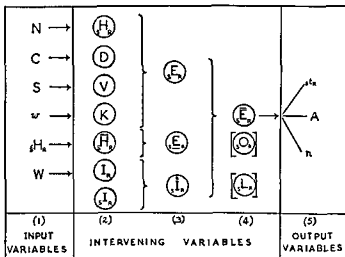


FIG 1 —Summary of Hull s final system The input and output variables and the intervening variables are symbolized as follows in the figure

Column (1)

N number of prior reinforcements
C_D drive condition



Column (2)

$_sH_R$ habit strength
D drive
V stimulus intensity dynamism
K, incentive-reinforcement
$_s\bar{H}_R$ generalized habit strength from related habit
I_R reactive inhibition
$_sI_R$ conditioned inhibition

Column (3)

$_sE_R$ reaction potential
$_s\underline{E}_R$ generalized reaction potential
$_sI_R$ aggregate inhibitory potential

Column (4)

$_s\bar{E}_R$ net reaction potential
$_sO_R$ oscillation of reaction potential
$_sL_R$, reaction threshold

Column (5)

$_st_R$ reaction latency
A reaction amplitude
n number of non reinforced responses to extinction

(From Hilgard, 1956 p 151)

perceptual organization The position was originally stated by such Gestalt leaders as Koffka and Kohler and adopted later by Lewin Adams Zener and most notably Tolman Tolman is outstanding among the S S theorists in restricting his use of the intervening variable to terms of the environment and the resulting behavior Other Gestaltists notably Kohler have been keen to link their hypothesizing to underlying neurophysiological traces and electrical brain fields Tolman specifically gives age as the second of his four individual difference variables the HATE symbols for heredity age training and endocrine condition but the variables have remained at the programmatic stage There have been attempts to state Tolman s theory more formally Olds (1954) suggesting a neural model for a sign Gestalt theory and MacCorquodale and Meehl (1953) expressing the theory in a formal set of twelve postulates They explicitly make the effort to state terms such as expectancy cathexis and valence in symbols similar to Hull s and the basic formulae of the two theories as so stated are surprisingly close This kind of reconciliation is indicative of the general rapprochement which is discernible among learning theories today It is in part possible because the two major classes of theory are primarily interested in different stages of learning and while there are definite disagreements between them which cannot be reconciled there are on the other hand areas where both may be right for they are emphasizing legitimate processes in learning Where the experimental conditions are selected specifically to illustrate the concepts it is not surprising that they should demonstrate their importance but this does not necessarily exclude the operation of other processes in other learning situations This is largely a matter of emphasis and selection

AGING AND PERCEPTUAL THEORIES

Theories which are primarily concerned with perceptual reorganizations are attractive to the gerontologist The experimental evidence would suggest that an older individual has so much difficulty in restructuring some percepts that much of his handicap in these cases may be due to this initial assimilation of material Welford (1958) goes so far as to conclude Much of the apparent difficulty of older people is not due to any true incapacity of learning or recall as such but to inability to comprehend the material or to deal with the conditions under which it is presented The conditions are mainly those of speeded and paced tasks which allow an individual little opportunity to rehearse or examine material It would be unfortunate if the assimilation stage were to be divorced from learning of which it is an integral part but it is of exceptional interest where assimilation can be identified as a focal point in aging studies To date there are not sufficiently definitive experiments to say why older subjects are slow in comprehension and how far this varies with different classes of material It is known that in everyday perception the individual selects only a small part of the total stimulus array and that his selection is mainly based upon his own past experiences (Bartlett 1932) If the slow assimilation of older subjects were entirely a matter of ambiguity or unfamiliarity it might be expected in those situations where there was little ambiguity or at least where the percept was in conformity with a subject s experiences that an old individual would respond as quickly as a young but what evidence there is on the subject does not suggest this (Wallace 1956) Again on Gestalt principles certain types of percept should be much easier than others and should remain so irrespective of experiential factors but it is not known whether this is so with older subjects These theoretical issues need to be experimentally examined

Mediational Theories

Since the differences between perceptual and behavioral theories have been repeated

for so long that most psychologists have come to believe in them the beginnings of some reconciliation between them as noted in the last section, is encouraging In accentuating different stages of learning, the behaviorist had followed an input output analysis and ignored all the S R and its immediate variables, while Gestalt tradition had concentrated upon the perceptual reaction and largely ignored the response Woodworth (1947) has tried to show that there is no obvious incompatibility between the two types of theory and that both the perceptual and the reinforcement processes are necessary for learning He conceives of learning as bringing about a change in the significance of the stimuli but this is achieved as a result of reinforcement "The new learning, the conditioning is sensory and not motor The change that takes place in the subject during the process of conditioning is a change in his way of receiving or perceiving, the sequence of stimuli" Woodworth goes on to point out that the responses may be old and perfectly familiar movements and that what has to be learned is a distinction between stimulus objects There is gradually built up a perception or registration of the sequence of events He sees no difficulty in perception being motivated, for he argues that it is not a passive affair but is driven by 'the will to perceive" Woodworth at this point would seem to be arguing that perception is itself a response and subject to similar motivational influences as other responses what has so often been considered a reinforcement of the motor response in say, a conditioning experiment is in fact a reinforcement of the new perceptual response Osgood (1953) has based his mediation hypothesis upon this process or as he puts it, "a more explicit formulation [and translation into Hullian terms] of the origin, nature, and function of 'sign Gestalt expectations'" In Osgood's system a mature organism might learn either by bringing about a change in the significance of a sign (the familiar buzzer is now perceived to mean "danger") or by a change in the instrumental sequence elicitated by a mediator (the buzzer still signifies "danger," but something other than running must be done) This is reasonable enough, but it still leaves open for debate the nature of such mediating processes, 'it is only experiments that bear crucially on the mediating processes that will make possible a choice between competing theories of learning' (Hilgard, 1956)

Motivation

It will have been observed that, though motivation is the core of so many learning theories from Freudian psychodynamics to Hullian behavior systems there is no general agreement on the operation of this basic variable Psychologists have felt it incumbent upon them to say why an organism does behave as it does, but they have assigned widely different answers to the question An extreme position is taken by Tinbergen (1951), who states "Even psychologists who have watched hundreds of rats running a maze rarely realize that, strictly speaking, it is not the litter or the food the animal is striving towards but the performance itself of the maternal activities or eating ' For Tinbergen the activity is necessary to release the "need" Deutsch (1953) will have none of this, the activity merely increases the chances of the organism's meeting with the appropriate stimulus For Deutsch a stimulus does not evoke a response, it terminates it" The experiments of Kohn (1951), Miller and Kessen (1952) and Berkun *et al* (1952) do support this thesis that, when appropriate stimulation has occurred, activity ceases, irrespective of what behavior the animal may or may not have carried out—and in these cases even though the chemical change which occasioned the activity persisted Guthrie (1952) asserts that reward is a secondary principle, benefiting learning because it removes the animal from the stimulating environment and thereby preventing new responses becoming attached to the clues which led to the correct re-

sponse Tolman is influenced by the evidence from latent learning and does not regard reward as a direct strengthener of response tendencies Hull on the other hand conceives of reinforcement in terms of need reduction such reinforcement being med ated by reducing the stimuli associated with the drive (stimulus reduction)

With such a variety of basic postulates all further supported and extended by concepts of secondary reinforcers the theorist interested in aging is in a dilemma He is aware that with human adults many habits are motivated by secondary reinforcers if indeed they have not become functionally autonomous (Allport 1937) Turning to lower organisms he has had to ask more simple minded questions mainly of the kind whether differences in the rates of learning of older organisms may be due to differences in motivation The assumption is that learning is more efficient if motivated as indicated by some differential reward experiments and the greater efficiency of directed learning over incidental If older organisms are slower in some learning tasks could this also be due to lesser motivation? Curiously enough this is no easy matter to settle The obvious procedure of depriving animals of food or water for equal time periods and then examining their learning under such deprivations does not yield a clear cut answer We do not know if old and young rats starved for the same time are equally hungry or equally motivated It is not straightforward how we allow for differences in body weights between old and young and yet have comparable animals in other respects These difficulties are brought out in Stone s (1929) series of studies and in the contrasting results of Verzar McDougall (1957) which are fully discussed by Jerome (chap xix)

In view of the complex issues raised by these experiments one possible fruitful approach may be indicated by the series of studies upon the role of the ventromedial *nuclei of the hypothalamus in controlling* eating behavior It has been shown by such workers as Brobeck (1946) Mayer (1952), Kennedy (1950, 1953) and Teitelbaum (1955) that rats with lesions in the ventromedial nuclei of the hypothalamus at first eat voraciously and rapidly become obese But with increasing deposition of fat this is followed by a second stage during which the animals eat much less though maintaining their excessive weight. If at this stage they are fed an unattractive diet consisting of a mixture of standard food with a percentage of non nutritive kaolin or cellulose such rats lose weight rapidly and take much longer than the young control animals in adjusting to the new diet. Two features seem to predominate as a result of the hypothalamic lesions (*a*) the rats are unable to regulate caloric intake on the one hand eating excessively and on the other making no compensation for caloric dilutions and (*b*), when the hyperphagic animals become obese they exhibit an increased sensory discrimination against an unattractive diet Kennedy (1950) observes that the older animals (precise ages not stated) resembled the operated rats in their feeding behavior, the palatability of food influencing their weight much more than in the case of young rats Further research with older animals in this field is obviously indicated

Functionalism

As we have seen the more elaborated theories of learning have been little used to date by psychologists interested in ag [illegible] hapter [illegible]

have been derived from a variety of approaches but to which the generic term functionalism might be given *This is not* to say that these researches directly [illegible] Chicago [illegible] by a [illegible]

tions As Wright (1957) puts it

The experimental approach most frequently adopted has been formulated by Melton (1950) in the statement that the most fruitful way to experiment on learning is to discover and explore the dimensions of variation In any learn

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these conditions separately and jointly influence the characteristics of learning behavior was seen as the main task of the experimenter in this field and the outcome of such experimentation was the formulation of a great number of functional relationships specific to particular laboratory conditions

This kind of research did not result in any unified theory and certainly it gave rise to no program of research which was attempting to examine the learn ng process as a whole But it did lead to a series of studies of varying intensity which attempted to analyze the significance of particular variables these might be the role of practice the rate of learning transfer of training etc From such studies some of the most lasting data of psychology were derived and certain relationships were sometimes observed which could be combined to form a higher order generalization Individual differences were taken into account and it *was congenial within this atmosphere for* the aging specialist to examine the role of his selected variable chronological age in much the same way as his co workers were selecting the variables of their choice Representative of studies from this standpoint is McGeoch s (1942) excellent review of *aging*

The major part of the work to be discussed in this chapter stems from the functionalist family but before turning to these aging concepts we will consider the specific contributions to learning from the two previously cited influences physiology *and the physical sciences*

IV Neurophysiological Theories

There is something direct and appealing in the effort to explain learning processes in terms of a neurological system and, with increasing advances in neurological knowledge it was inevitable that such speculations should be made But they were far from conclusive in their first stages and the early findings revealed a succession of complexities with few hints as to their solutions *Lashley s early ablation studies* with rats led him to formulate the theories of mass action and equipotentiality and this non specificity of function within a given region left the would be experimenter of that time with few precisely testable hypotheses The immediate results of Lashley s *(1929)* early work was to check enthusiastic speculation for it suggested no *way out of the impasse*

Influence of Subcortical Structures upon Learning

A marked change has taken place during the last decade primarily because of a synthesis *of findings from many related fields* and particularly from electroencephalography and developments in the work of micro electrode implantations This has changed the emphasis from one where attempts were being made to assess the effects of surgical intervention on learning *to one where the experimenter is trying to* measure the actual activity of a neurological member during the course of learning This became possible when the relatively crude listening in techniques of scalp electrodes could be supplemented by micro-electrode implantations The preliminary findings of electroencephalography had made it clear that stimulation was not entering an inactive field but that the stimulus was received against a background of electrical activity which was taking place continuously in the cortex The obvious effect of a stimulus was to change the resting electrical potential More recent work has shown that the conditioned stimulus comes to block the alpha waves *in a man*ner that parallels the development of the conditioned response in time Such a conditioned stimulus may arouse new cortical

waves whose existence seems to depend upon the learning process (Galambos and Morgan 1959) Thus learning is not an exclusively cortical process but is influenced by the antecedent neural activity in these sub cortical areas The end result to be sure is the production of a more or less permanent change somewhere but antecedent events determine where and even whether it will occur (Galambos and Morgan 1959) It is now pertinent to ask what is known about these permanent changes

Plasticity in the Nervous System

In his Ferrier Lecture Young (1951) claims that it is the most obvious failure of current neurophysiological theory to provide an account of the changing potentialities or plasticity of the nervous system Certainly as yet little is known about the way learning processes influence the functioning of the central nervous system but this has not prevented a whole series of ideas as to how this is achieved The most popular have been changes at the synapse For convenience these might be thought of as theories which primarily involve some structural or anatomical change and those which are primarily biochemical Eccles (1953) post tetanic potentiation theory is a current example of synaptic transmission being effected through chemical agencies Either kind of theory conceives of learning as being achieved through increased efficiency of the synaptic connections but the evidence to arbitrate between them or between theories which put forward the concept of rearranged neural circuits is inadequate It would appear that in view of the permanency of some memories under conditions where the brain has suffered injury of sufficient severity to impair the electrical activity of the cortex as in brain injury cases or hypothermal stimulation experiments involving learning (Andus 1955) that the consensus of opinion favors some facilitatory change probably at the synapse As an example of this kind of theory we will consider Hebb s (1949) provocative suggestions

Hebb s Theory and Adult Learning

Hebb s basic idea is simple enough and has often been made (Adrian Konnorski J Z Young) It is supposed that each time a neuron stimulates another or when the two together stimulate a third the connection between them is reinforced Hebb thinks that this is by the growth of synaptic knobs citing the evidence of such neurologists as Lorente de No On this basis Hebb suggests that repeated stimulation will lead to the gradual establishment of a cell assembly a diffuse structure made up of cells in the cortex and subcortical centers The cell assembly may be aroused either by a sensory event or by a preceding assembly action or normally by both and it will usually have a specific motor facilitation Where a series of cell assemblies are connected together we have a phase sequence the normal thought process In Hebb s system experience of certain stimulus situations will serve to establish autonomous central activities Early learning may be slow as the basic cell assemblies are established but once established they are permanent and subsequent learning is based upon them As a result the later learning of adult life may be rapid and insightful that is where it is related to well organized phase sequences

Hebb s thinking has been influential and deservedly so His model as he himself concedes may well be wrong in its neurological details but he has shown how by accepting the known facts of neurology it is possible to construct a theory which is not against the known psychological evidence And much of Hebb is sound psychology particularly with respect to adult learning If in fact the adult has set up a neurological organization similar to the pha e sequence then we should except his responses and his learning to be quick and accurate in those instances where environmental stimulation accorded with his pre-

vious experience Further it would follow that in those cases where it did not so accord the adult would be handicapped for not only would he be trying to establish new cell assemblies which is a painstaking and more difficult process but that process would have to take place in competition with the established phase sequences That is to say every time it was possible for an established response to be made the organism would be facilitated toward making it whether it were correct or not On Hebb s system the older the organism the more practiced would certain phase sequences become and it may be added probably the fewer the cells which were not linked into some assemblies Thus while it might be easy enough for a stimulus to trigger off an established response it might become increasingly difficult to set up a new Of course this part of Hebb s theory is not different from many previous formulations Bartlett s (1932) idea of schema and the dominant role of previous experience would suggest identical results but it is the effort to relate psychological facts to neurological findings that distinguishes Hebb s work

Clinical Investigations in Neurology

Another class of neurological research has provided a very different kind of evidence which is most material to aging The studies which have been made upon brain injured patients may be thought of as the counterpart to the ablation studies which have been conducted with infrahuman species While the latter have the advantage of more precision and control the human studies have been able to provide a more over all picture of the variety of phenomena which are to be expected from the system when it suffers interference Certain features of the amnesic syndrome in particular are relevant to aging

THE AMNESIC SYNDROME

It has long been recognized that judgment of time may be grossly disturbed in amnesic states with organic pathology Korsakoff in his exposition of the psychoses which have come to bear his name pointed out that memory for time is often more severely affected than memory for events Van der Horst stressed that many of the errors of memory are due not so much to loss of retention of recent events as to their temporal reference An example would be when a patient recognizes a doctor who returns to his room after a few minutes absence but states that the doctor had been there on the previous day Gillespie (1937) is in agreement with Van der Horst that the time ordering of experience may be a primary mental function though workers such as Mayer Gros and Guttmann (1936) have objected Lidz (1942) was prepared to emphasize the temporal and sequential difficulties but would attribute the defect primarily to an inability to recall The feature which is so common to both chronic and transitory states is the tendency to antedate recent events as is brought out so clearly by Williams and Zangwill (1950) As these authors point out it might at first appear that this antedating of recent events could be attributed to the lack of clarity or intensity of the recollection but that this alone could certainly not give rise to the abnormalities which are found In normal life many hazy recollections can be correctly attributed to recent occurrences and conversely vivid memories are known to have arisen in the distant past In amnesic cases where the retention of a whole sequence of events is impaired it would seem probable that it is the isolated quality of the particular event which is responsible for this gross overestimation of the time interval since the actual experience

One may hazard the view that an amnesic patient attempting to date an event which took place a few minutes earlier is in much the same position as a normal individual attempting to date an event which took place some days or weeks previously In both cases the original event is retained in memory but lacks a firm anchor in the memory train In anterograde amnesia any recent event which is retained in

memory has a certain quality of isolation It is devoid of firm chronological links with neighbouring experiences which have preceded or followed it [Williams and Zangwill 1950]

IMMEDIATE MEMORIES OF AMNESIC SUBJECTS

In view of this antedating feature of the amnesic cases we may ask what happens in the case of their immediate memories and their ability to repeat material such as as digit sequences and sentences or paragraphs As with older subjects (Gilbert, 1941) the amnesic does not exhibit a marked decline in digit span Even in gross conditions such as the Korsakoff patient exhibits immediate memory may be remarkably well preserved This contrasts strikingly with dysphasic conditions where the capacity may be well below normal in patients who otherwise have recovered from an aphasic disorder Zangwill (1946) cites the case of a gross amnesic patient who could learn the Babcock sentence but when shown it two days later alleged he had read it in a paper two or three months before By contrast a dysphasic patient when told the sentence eight months after he had unsuccessfully tried to memorize it, could recognize it and remember his failure to learn

RETROGRADE AMNESIA (R A) AND POST TRAUMATIC AMNESIA (P T A)

In cases of closed head injury resulting in loss of consciousness *it is found that* there is a loss both of the ability to remember those events which preceded the accident (R A) and those which succeeded (P T A) The duration of R A and P T A are closely associated P T A would seem to follow mainly from the impaired perceptual abilities of the patient who may be in a semi or unconscious state But retrograde amnesia poses several problems which are central to learning The clinical situation is inevitably complex, but the general picture is fairly consistent Let us first consider less severe cases A patient has registered a number of events in the course of his normal activities, suddenly these actions are terminated by injury, he loses consciousness, and on later recovery he is at first unable to recall some or all of the *events* which preceded the accident. With the gradual remission of the post traumatic confusional states, a patient tends to recover the events preceding the accident in inverse relation to their recency There is a gradual filling in of the amnesic gap until he achieves a coherent memory of events up to a few minutes before the accident. This has been called the gradual *shrinkage* of the forgotten period This is of course an abbreviated account of the process and certainly with more severe cases the shrinkage does not necessarily follow this temporal pattern so closely Here the original gap of lost events may cover hours or days and, in exceptional cases, has been known to extend over several years so that the patient may even believe himself to be younger than he is Though it is usual for the distant memories to return first, careful examination of the amnesic period has brought out the presence of ' visions or islands of memory within this period (Russell and Nathan, 1946, Williams and Zangwill, 1952) It may be concluded that the evidence suggests that such injuries to the brain have far more effect upon recent than upon remote memories It would also seem that the vulnerability of the lost experiences depended more upon their nearness in time to the injury than their significance to the individual

ELECTROCONVULSIVE SEIZURES (ECS)

The above conclusions are confirmed both with the clinical and experimental administration of electroconvulsive seizures Human patients undergoing convulsive therapy tend to forget more recent events and this has led to experimental attempts with animals to examine what are the specific effects These have proved complex particularly with conditioned emotional responses which proved most vulnerable

(Brady *et al*, 1955), but one finding is particularly relevant Duncan (1949) showed that, if the shock was administered *immediately after learning, his rats failed* to learn an avoidance task, while rats receiving the shock 1 hour after learning were not adversely affected Rats receiving the shock at intermediate delay times—20, 40, and 80 seconds, 4 and 15 minutes—showed the expected intermediate degrees of learning Thompson and Dean (1955) have shown similar results for discrimination learning The parallel between these findings *and the retrograde amnesic cases are* clear enough—memories are not instantly established in a durable form If they are to become permanent the process requires time The challenge now is to determine the nature of that process The evidence to date would suggest that it is a process which becomes more vulnerable with older subjects

CLINICAL STUDIES AND AGING

These studies with clinical patients are as yet more important to learning theory in the richness of the phenomena they reveal than in pinpointing the anatomical locus of particular functions The phenom
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of subjects it is observed that immediate memory, as measured by digit span and sentence learning is not radically impaired Yet recent memories are particularly vulnerable and, *in the case of senile patients,* may be especially dramatic It cannot be assumed, as with the retrograde amnesic cases, that an older subject's perception and assimilation of material are unimpaired Indeed, it may well be that often memory deficiencies in the aged could be ascribed to the inadequacy of the original perception But with due consideration for this, there are enough examples where forgetting could not be so attributed and where the loss would have to be put down to some failure of storage It might be argued that such failure should be ascribed to recall But, insofar as older subjects can recall their "longer term" memories, it *would be incumbent upon us to explain* why the recall mechanism was intact for these older memories and not for the new On the other hand, if it is assumed that the newer memories are not at the same strength as the old, then no further assumptions are necessary Recall is adequate where there is an adequate residual experience (trace) This would then present the problem as to how the differential strengths *in the old and new memories had arisen* Are they to be attributed to decay at a particular part of the system as might be caused by an inability of a new experience to coalesce with an old? This would suggest a transmission difficulty between the perceiving of events and their storage in a longer term system It would seem that there is here a definite experimental program to determine the conditions under which immediate experiences are particularly vulnerable for older subjects Some of the known facts as they relate to the problems of decay and interference will be discussed in the section on short term memory (see below, "Short Term Retention and Recall")

V MATHEMATICAL AND RELATED THEORIES

As already noted, the influence of mathematical concepts has increased considerably in present day psychology, and there *are now several mathematical models* such as Estes' (1950) statistical model of Guthrie's theory and Bush and Mosteller's (1951) mathematical model for simple learning However, the mathematical influences which have been most productive to date have been those which have been identified with developments in other branches of science, notably those connected with information theory, cybernetics, and games theory It would seem that psychological experimenters caught the impetus from these current advances and not only re-

lated their concepts to psychological phenomena but succeeded in examining them in an experimental context This has been particularly true of concepts developed from the principles of control and communication mechanisms

Cybernetics and Communication Theory

It is one of the principles of cybernetics that a mechanism can be self-adjusting by means of 'feedback" If some representation of the total output is fed back through the system, it can automatically be made to control further output either by 'positive feedback" which reinforces the direction of flow, or by "negative feedback," where the directions are opposed, so that the feedback counteracts the input and prevents it from exceeding a particular value Feedback quickly became one of the most widespread and abused ideas of psychology, for the analogies with homeostatic mechanisms were all too obvious Even so, the concept of man as a communication channel in which signals travel both from and to the environment, and in which further signals arising from the system's own responses are also fed back is a strikingly close analogy with man made self regulatory mechanisms In the field of motor skills sensory impulses, both exteroceptive and proprioceptive feed back signals about the response, so that the necessary adjustments may be made to complete it By manipulating this feedback, which can be considered as a form of knowledge of performance, the operators' task can be simplified or complicated (Annett and Kay, 1956, 1957)

Information Theory

Communication engineers provided psychologists with a further experimentally productive concept in information theory As used here, information is a statistical measure of uncertainty, the less probable an event, the greater being the information it carried Where two events are equally possible, we need one binary unit ("bit") of information to decide between them, where there are four, we need two "bits," and so on Technically, the amount of information is given by the negative logarithm of the probability for that event The attractive feature of this measure for the psychologist was in allowing him to quantify a wide range of psychological events that had not hitherto been so treated For example, he might measure the information in nonsense syllables drawn from a known population or in a visual signal in a choice reaction time experiment (Hick, 1952, Hyman, 1953) Again, the uncertainty concept can be applied not only to the input in a motor skill but to the output. It has been shown that in a simple assembly task, where the subject had to place pins in apertures of varying tolerances, that the speed of the operation was related to its information content (Fitts, 1954, Annett *et al*, 1958) Over a wide range of amplitudes and tolerances the rate of transmission was constant It is unlikely that this simple predictive model will fit all cases, but it is illuminating to examine where it does and does not accord It is the beauty of information theory that, where we do find quantitative differences, not only are they indexes to qualitative effects but the actual sizes of the differences can be held to be lawful consequences of the imposed conditions (Leonard, 1955) For this reason the application of these kinds of study to aging is attractive, since they allow us to make more exact comparisons It has long been thought that older subjects are prone to act on expectancies and ignore legitimate contextual possibilities Information theory analysis would provide a measure of how far a subject was deviating from conditional probabilities and whether or not old subjects do this more than young Put another way, it could show in a variety of tasks whether their rate of transmission of information was different from that of young subjects, and what circumstances, if any, determine this behavior (Crossman and Szafran, 1956) Since it is popularly sup

posed that old people are more cautious in their habits thus direct measure of their actions under conditions of manipulated uncertainty would be an ideal measure to employ

VI Theoretical Constructs Employed in Aging Studies

So far we have considered some of the major theories in learning as put forward by psychologists neurophysiologists and biophysicists In the main aging has been very much a peripheral interest in such work though many of these formulations would be suited for aging studies The contributions to be discussed in this section are more directly related to aging phenomena and the task is to evaluate the significance of these approaches

Maturation Degeneration

On the assumption that learning abilities improve with age up to maturity and that they then remain constant over the next decade from which point they show a gradual decline certain hypotheses have been advanced and have remained in vogue for some time Of these the maturation degeneration hypothes s is the most popular

The facts of the increasing learning ability of children as they get older are well known and the maturation hypothesis sought to explain them on the grounds of organic growth comparable to the more observable bodily growth processes Such organic growth was not clearly defined and might mean a maturation of the sensory and motor mechanisms required for learning a maturation of the modifiability or plasticity of tissue or a maturation of any neurological system for which the individual investigator had a pred lection It was all delightfully vague but not seriously challenged because of the plausibility that as a child grew older some of its development was to be attributed to organic growth rather than experiential factors

This approach was taken over by the converse hypothesis of degeneration at the later end of life Where performance declined it could be attributed to a degenerative process but the difficulty of this *ad hoc* explanation is more apparent with the degeneration hypothesis than with the maturation one It may be argued that in old age the organism has a smaller number of brain cells that there is in general a lowered neural activity and that in some cases the electroencephalogram shows evidence of disorganization but evidence of this kind would hardly be sufficient to account for the changes which are found in some learning tasks with subjects in the thirties and forties Nor would the degenerative hypothesis explain the differential decline which is found with some tasks and not with others On the one hand we have the facts of reported decline in learning tasks with some older subjects and on the other those suggesting that the growth and regeneration of tissue become slower with age but the connection between the two is quite unspecified Any work relating the two would be of the highest interest but has yet to be done

A particular variant of the degenerative hypothesis ascribes learning to a loss of the native plasticity of the nervous system We have already seen how little is known about this Plasticity as James described it is the possession of a structure weak enough to yield to an influence but strong enough not to yield all at once Ruch (1934) considered that loss of learning ability might be attributed to a condition of lowered plasticity of tissue and attempted to examine this in a study which demanded that the subjects learn tasks which required extensive reorganization of pre existing habits Thus his subjects learned not only a pursuit rotor task but its mirror reversal while in the verbal tasks there were paired associations of commonly associated words nonsense equations of the $R \times J = Y$ variety and such false equations as $2 \times 5 = 8$ Ruch considered that his results yielded the deficits predicted on his plasticity assumptions but this has been

doubted (Kay, 1953, Welford, 1956) Ruch s tasks varied along several dimen sions and in particular the complexity of the tasks was manipulated to an unmeas ured degree The influence of task com plexity is indicated in Korchin and Baso witz's (1957) study where they repeated some of Ruch s experiment and did not find the predicted decline with the interference material

But the plasticity hypothesis raises an issue which is common to much psycho logical theorizing Phenomenally it is ob served that older subjects show a lack of adaptability Their behavior is rigid This description of behavior is then transferred to a neurological state such that the pro posed hypothesis is only a redescription in neurological terms of the same process which was observed of the phenomena The behavior was rigid so now is the nervous system The step which has been taken is not necessarily wrong but it is valueless without the support of further evidence Explanations of this plasticity kind are in one sense bound to be right by the same token they explain nothing until they re- ceive further support Systems of course need not be mere reduplications of the phenomenal features which they are pur porting to explain There is no eye or lens in the television set And there is a danger that by making the system imitate too closely the phenomena it is attempting to explain further difficulties are being cre ated as in the case of some remember ing theories (Kay and Skemp 1956)

Transfer

As noted in the last section Ruch's ex periment varied the material so that he might manipulate its familiarity to a sub ject This differing experiential factor brings us to the problem of the transfer of train ing Transfer has long had the status of a separately titled subject though there is a case for saying that all learning is an ex ample of transfer insofar as one learning situation is never identical with another, even in the controlled Pavlovian experi ments This is obvious enough, but the distinction between learning and transfer has persisted, it is particularly thin in many examples of adult learning It should be noted at the outset that under the one title of ' transfer" a variety of quite dif ferent variables has been assembled In trying to identify some of them, it is pro- posed to note first the wider and more general usages of the term and then to turn to more specific instances

"MODUS OPERANDI '

In their excellent chapter on transfer McGeogh and Irion (1952) discuss the relevance of general factors common to two learning tasks, citing as the most im portant the transfer of general principles, modes of attack, and sets to perform Though it may often be convenient to dis- tinguish these usages, in many instances it would seem that what is being stressed is that the stimulus in a present situation is operating in relation to a whole back ground of past experiences In such circum stances the stimulus has a role to play, but it is far from the sole determiner of be havior And it may well be that a whole assemblage of psychological terms of the set attitude, and hypotheses variety, which appear to be referring to very different facets of behavior, are covered by the same mental operations, as Hebb has pointed out For this reason these general heads will be discussed under the same neutral term *modus operandi*

It is not surprising that an individual should carry over from one activity to an other a general form of procedure This belief is the rationale for trying to in culcate habits of neatness and accuracy in school children, but the transfer effects have not always been marked in those experi ments which have tried to verify these as sumptions (Coxe, 1924, Stroud, 1940) Where the habits or principles have been stressed and their general application brought out the effects have been more noticeable (Bagley, 1905, Judd, 1908) In studies of this kind the attempt is being

made to show that the individual so builds up a habit strength that it governs his mode of operations over a wide range of tasks This can certainly be illustrated over a restricted range of tasks and at a preverbal level In a celebrated experiment Harlow (1949) taught his monkeys to solve a discrimination problem using one set of variables, which he then reversed In time the monkeys learned to respond immediately to this reversal, in Harlow's words, they had learned how to learn, though, to be more accurate, they had learned what to learn, insofar as they had learned the particular variables to respond to in that particular setting It would be relevant to a concept of "learning how to learn" to investigate the range of stimuli and responses which show transfer effects with these reversal problems

Of course such transferred acquirements do not always facilitate learning In his experiments on "Mechanization in Problem Solving" Luchins (1942) demonstrated with adult subjects that a learned procedure continued beyond the point where it was facilitating and persisted to where it eventually completely impeded progress Here the general issue seems fairly clear Faced with a new situation, an individual considers only a limited range of possibilities and procedures, he is much more likely to engage in those where he has already acquired proficiency In a world of probable things he will try to advance using those methods which he has found profitable in the past It might be said that these have been reinforced and that to this extent they now dominate in strength over other habits which have not been reinforced to the same degree

THE GENERALITY OF THE PROCEDURE

This same tendency may be illustrated in situations which are not usually thought of as showing transfer phenomena but are generally classified as the dominance of attitude or set In a recognition study (Zangwill, 1937) adult subjects were asked to look in turn at six ink blots which the experimenter said would remind them of mountain scenery After naming these blots, they were shown another six which were supposed to remind them of common animals, and they were asked to name these In general, the subjects failed to notice that one of the ink blots was common to both series, and two thirds of them gave it a topographical location in the first series and dubbed it an animal in the second Here we have one stimulus pattern, but a subject's previous experience leads him to expect one solution in the first situation and a different one in the second In other words, subjects responded to the situation not as one in which there were any number of equiprobable solutions but as one in which certain categories were much more likely than others In the experiment this behavior has not paid off, but the advantages and economy of the procedure should not be overlooked It would be extremely time-consuming and in many situations impossible, for the human system to react to all stimuli as if they were equiprobable Furthermore, since life for the adult is so much more a matter of responding to familiar rather than unfamiliar stimuli failures outside the laboratory will be fewer It would seem that this selective reacting to probable stimuli in the environment becomes an established mode of operation for the organism and is to some degree "functionally autonomous", that is to say the procedure is capable of perpetuating itself, since the responses to the more probable stimuli will also be reinforced more frequently Where the organism is so far out of its familiar environment that it can no longer select the probable stimuli, it has to make some adjustment, that is, it has to learn If it cannot, it faces disaster, so long as it stays within that unfamiliar situation

TRANSFER OF STIMULUS RESPONSE RELATIONSHIPS

These are some of the general attributes of transfer, but efforts have been made to examine the subject much more specifically As so often, it is appropriate to begin with

Thorndike and his opinion that transfer depended upon the presence of identical elements in the original and the new learning. Facilitation is provided by such elements. At first sight this seems reasonable enough provided the elements can be identified. Experimenters turned to the stimulus and the response. But the relation between transfer and the similarity of the response and stimulus elements in the two learning tasks is not a simple linear function. If the elements are identical, then maximum transfer may be expected, since it is merely learning the same task; but, when the elements are as different as possible, this does not give maximum negative transfer (interference). This result is brought about by the intermediate case, as illustrated in Wylie's (1919) generalization that the old response to a new stimulus yields positive transfer and conversely, that the new response to an old stimulus would yield negative transfer. This is only a half truth if it is a truth at all, but it brings out clearly enough the necessity for grading the degree of similarity of stimuli and responses. Skaggs (1925) and Robinson (1927) attempted this in their formulation, and a more sophisticated version was put forward by Osgood (1949) in his transfer and retroaction surfaces. Osgood's diagram (Fig. 2), which represents a higher order generalization, usefully summarizes many of the findings from earlier work. It is perhaps easiest to think of the figure as the surface of a cam giving a zero transfer reading where we have a neutral stimulus and an antagonistic response, a maximum positive reading where stimulus and response are identical, and maximum negative (interference) reading where the stimulus is identical and the response antagonistic.

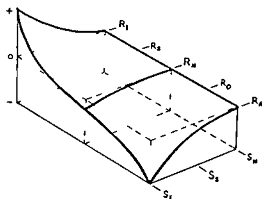


FIG. 2.—Osgood's transfer and retroaction surface. (After Osgood, 1949.)

As Osgood points out, the next step would be a mathematical model of his surface so that its various points are more precisely related, but the difficulties here are considerable, since the scaling of identical and antagonistic responses is no obvious procedure. Attempts to achieve this might be made with motor skills, where discrete stimuli and responses can often be identified and measured. Gagne *et al.* (1948), in a series of studies upon the components of motor skills, have stressed the desirability of being able to compare transfer expressions involving different learning tasks. They discuss several formulas that would relate the transfer obtained to the total possible improvement in the task. These are of the kind shown in the formula at the bottom of this page. This would certainly allow some comparison between transfer results at different tasks though from a psychological standpoint it might be desirable that the tasks did not differ radically in their degree of difficulty. A further and most useful criterion satisfied by the formula is that it makes it possible to relate the transfer obtained at different stages of the same task to the total possible improvement. This is valuable, since there has been a tendency to place too much stress upon the initial effects of transfer; it may be of interest to know what happens on the first trial, but it is of far more interest to find out how permanent is the effect.

$$\text{Percentage transfer} = \frac{\text{Experimental group score} - \text{Control group score}}{\text{Total possible score} - \text{Control group score}} \times 100$$

GENERALIZATION AND DISCRIMINATION

This last point is brought out in the papers of E J Gibson, who proposed a generalization differentiation hypothesis for verbal learning The first and fundamental part of learning is the establishment of discrimination among the items to be learned This is brought about by means of the reinforcement of correct responses and the non reinforcement of errors To this extent, Gibson's generalization gradient is being used in a Pavlovian sense and is equivalent to a similarity scale or might even be named a 'confusion gradient' If there is no discrimination between items at the beginning of a task, then learning time will be at a maximum if such discrimination already exists, it will be at a minimum Where there is no discrimination, generalization will increase to a maximum or peak during the early stages of practice with a list, after which it will decrease as practice is continued 'Positive transfer will occur in situations where the nature of a second task permits discrimination acquired in a previous task to be beneficial Negative transfer will occur when generalization with a previous task occurs, but where the situation is such that discrimination between some aspect of the two tasks themselves is required' (Gibson 1940)

Many of the predictions which follow from Gibson's approach are open to experimentation Some of them will be considered in the following section on retroactive and proactive inhibition Meanwhile it will be observed that the consequence of the Gibson hypothesis is to move the subject of transfer of training into a more central position in the learning process We are now speaking not only of the effect of one task upon another but also of how the learning of material may influence the learning of other material within the same task This is a unifying step Transfer is brought within the learning process itself For aging studies this is relevant, since a normal adult subject approaches any task with a hierarchy of general habits and highly differentiated responses It would follow from Gibson's hypotheses that these established differential responses would place him at an advantage in many circumstances It would also follow from the general concepts of transfer that one stage of learning where an older subject might differ from younger would be in the initial assimilative processes

Retroactive and Proactive Interference

This subject is another facet of the transfer problem It has been extensively reviewed by Britt (1935), Swenson (1941), McGeogh and Irion (1952), and Woodworth and Schlosberg (1954) Again, we are trying to say something about the effects of one activity upon learned activity, and, in general, this has come to mean the effect of learning one task upon the learning of another, though there is no reason why the interpolated activity should be that of learning The normal design for retroactive studies has been as shown in the outline at the bottom of this page There are several variables which may be manipulated here First, there is the time when the interpolated activity occurs, which may range from immediately after the original learning to immediately preceding the measure of recall This variable is in part governed by the total time elapsing between the original learning and the recall task Second, the kinds of material to be learned in the interpolated and the original task may be varied from being completely identical to completely opposite Third the degree of learning is likely to have a profound effect, as we have just noted with differentiation (see above, "Generalization and Discrimination")

	Original Learning	*Interpolated Task*	*Measure of Recall*
Control group	Learn Task 1	Rest	Recall (or relearn) Task 1
Experimental group	Learn Task 1	Learn Task 1*a*, , *n*	Recall (or relearn) Task 1

From these wide dimensions it will be apparent that the retroactive concept is not confined in its effects to any one stage of learning—the assimilation the retention or the recall Most experiments have measured the end product either by recall or by relearning and then made inferences as to where the influences had operated It should further be noted that the same terms have been employed with widely different theoretical explanations in discussing this range of phenomena The following are some of the main demarcation lines

THE ORIGINAL RETROACTIVE HYPOTHESIS

Retroactive inhibition was first used by Muller and Pilzecher (1900) in trying to explain the effects of interpolated learning upon the recalling of already learned nonsense syllables They put forward the idea that there was some degree of continued neurological activity after the learning practice itself had ceased Ideally this perseveration or consolidation time should not be interrupted but where it was by further learning activities this would adversely influence the original learning Maximum interference would occur if the interpolated learning followed quickly after the original but there would also be some interference if it occurred immediately before the recall the assumption being that perseversation of the interpolated task would interfere with the recall of the original Here then we have the outline of the retroactive explanation basing itself upon a neurological perseveration of the original learning and an interference from subsequent activity

LATER VERSIONS

These are plausible postulates trying to explain phenomena which are still central in present day learning problems and they have persisted in many subsequent modifications of the theory Workers such as De Camp (1915) and Webb (1917) followed them in their linking of retroaction and transfer Where the original task had consisted of learning connections $S_1 R_1$ and the interpolated of $S_1 R_2$ it was argued that in the learning of the interpolated task the original $S_1 R_1$ connections intruded and were weakened while in the relearning of the original task the $S_1 R_2$ connection interfered with the re establishment of the $S_1 R_1$ connections In this same family of concepts belong Melton s two-factor theory where he proposed that in addition to the competition among responses at the time of relearning there was an unlearning factor occurring during the learning of the interpolated task (Melton and Irwin 1940 Melton and Lackum 1941) Melton s experiments showed that the overt intrusions from the interpolated list at the time of recall of the original list were not numerous enough to account for the amount of retroactive inhibition which was in fact found It was also claimed that the retroactive inhibition not accounted for by overt intrusions was too great to be attributed to any competition which might not have revealed itself in overt intrusions Melton proposed to attribute the residual decrement to a factor X which he identified as an unlearning of the responses in the original list when they occurred as intrusions during the learning of the interpolated list However plausible such an unlearning factor may be it should be pointed out that the procedure of counting the number of overt interfering responses is not a satisfactory measure of an interfering process and the procedure has been criticized (Bugelski 1948 1956) Furthermore the theory assumes that the unlearning factor increases as the amount of interpolated learning increases but it has been noted not only that there are a small number of intrusions during interpolated learning (Thune and Underwood 1943 Osgood 1948) but that they tend to occur mainly at its beginning

Efforts to examine systematically the age differences in transfer and retroactive effects are now in progress by Braun the first of whose papers has appeared (Gladis and Braun 1958)

PROACTIVE INTERFERENCE

From his theory Melton deduced that the retention of the original task would be less than that of the interpolated task on the grounds that the retroactive inhibition would be greater than the proactive In part *this would follow because the original* learning may be influenced by *both* the unlearning during interpolation and the competition during relearning while the extinction but it would also have the properties of spontaneous recovery with time

In his latest paper Underwood (1957) has considerably modified his views upon the roles of proactive and retroactive influences He examined a series of well known studies which satisfied the following four conditions (*a*) retention was measured by recall at (*b*) 24 hours after learning (*c*) the original degree of learning had

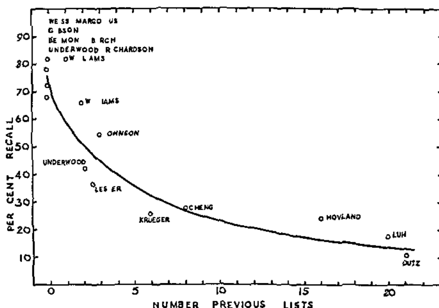


FIG 3 —Recall as a function of number of previous lists learned as determined from a number of studies *Left to right* Weiss and Margolius 1954 Gibson 1942 Belmont and Birch 1951 Underwood and Richardson 1956 Williams 1950 Underwood 1952 1953*a* 1953*b* Lester 1932 Johnson 1939 Krueger 1929 Cheng 1929 Hovland 1940 Luh 1922 Youtz 1941 (From Underwood 1957 p 53)

interpolated activity is only influenced by the competition Several studies—Melton and Lackum (1941) McGeogh and Underwood (1943) and Underwood (1945)—support this conjecture But Underwood (1948) found that when he extended the relearning time from 5 hours to 48 hours after the original and interpolated learning the difference between retroactive and proactive inhibition disappeared This might be explicable on the grounds that the unlearning has the features of unreinforced responses this would lead to experimental been to one perfect recitation and *(d)* under *conditions of massed practice* Underwood found that the greater the number of previous lists learned the greater the forgetting, which he interprets to imply that the greater the number of previous lists the greater the proactive interference The findings are summarized in Figure 3 It will be observed that the material is of several different kinds such as nonsense syllables geometric forms and nouns and includes paired associate and serial presentation Underwood comes to the dramatic

conclusion that "the classical Ebbinghaus curve of forgetting is primarily a function of interference from materials learned previously in the laboratory When this source of interference is removed, forgetting decreased from about 75 per cent over 24 hours to about 25 per cent'

It should be emphasized that Underwood is aiming to demonstrate that, where a single task has been learned in the laboratory and retention measured at some later time 24 hours or more little of the loss can be attributed to interference from activities outside the laboratory during the retention

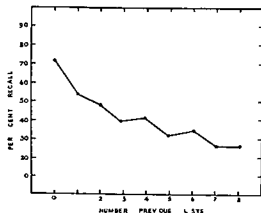


FIG 4 —Recall of serial adjective lists as a function of number of previous lists learned (From Archer see Underwood 1957 p 52)

interval He is not denying that an interpolated task given shortly after the original learning will not interfere with retention Underwood cites studies to illustrate that, under the conditions he has specified, recall is a function of the number of previous lists learned In one of these, by Archer, subjects learned lists of twelve serial adjectives to one perfect trial and recalled them after 24 hours The recall of one list always took place prior to learning the next list The results for nine successive lists are shown in Figure 4, where the percentage of recall falls from 71 for the first list to 27 for the ninth On the basis of this and similar studies, Underwood makes his case that the greater the number of previous lists learned, the greater the forgetting, which he attributes to increased proactive inhibition In discussing the findings, he seems willing to extend this proactive influence to learning outside the immediate experimental context "A 20 year-old college student will more likely have learned something during his 20 years prior to coming to the laboratory that will interfere with his retention than he will during the 24 hours between the learning and retention test."

This emphasis upon proactive influences is of considerable significance for aging studies Psychologists have gradually appreciated that learning will be influenced by antecedent experiences and have noted differences in initial learning speeds according to the similarity and 'meaning" of a task with a subject's previous learning But they have given much less weight to the influence of previous experiences upon retention once the task has been learned Underwood's paper redresses the balance He is not measuring the proactive effects, if any, upon the acquisition stage of learning but is content that all learning has been to the same criterion He then measures the proactive effect upon the storage and recall stages Future research will no doubt try to sort out at which of these two stages is the influence greater by using other measures than recall There are several other worthwhile issues Underwood chooses tasks which were only learned to the extent of one perfect recitation There is little overlearning with such a criterion, and after 24 hours there would be a distinct tendency to generalize the items from both lists (Gibson, 1940) It should be revealing to find out what interferences there are, if any, where the previous list or lists have been overlearned and where the test list has been learned in one case to the one trial mastery criterion and in another to a more stringent criterion The conditions of everyday learning reveal all stages of mastery, so that such studies would have practical as well as theoretical interest There is reason for thinking that the effects may be very widespread, for, as Davis and Sinha

(1950*a*, 1950*b*) showed in a retroactive study, interpolated material received by a different sensory mode and at widely separated time intervals, up to 1 month, generalized and caused confusion when the subject matter was related Further research will have to decide upon the proactive effects, where the degree of similarity of both the material and the situation is varied It will also have to determine whether learning immediately preceding the main task will have a greater proactive influence than learning which precedes by some time This will be no easy program, so much of adult learning may be influenced by previous learning, and, though Underwood's findings only relate to the negative results of this influence it would seem highly improbable that this is the complete picture The laws of learning have never suggested a law of diminishing returns from childhood on which would indeed be the case if Underwood's results were rashly generalized But he has suggested some of the circumstances under which such diminishing returns may be expected, other conditions need now to be examined and it would seem reasonable to look also for those which might be expected to yield increasing results Some are to be found in the experiments in the following section

Early Environmental Influences

Experimental work has indicated that the learning ability of a species is not genetically determined but is profoundly modified by environmental influences and that the organism is particularly susceptible to some influences at certain critical periods during its development Much recently, exciting work has been devoted to the old issue how far the organism learns to see (Hebb, 1949) and how far instinctive processes may be understood in terms of the organism's innate capacity to respond to certain sign stimuli in the environment This has led to the realization that some so-called instinctive acts were "learned in a single trial"—imprinted (Tinbergen, 1951) Closely related with these studies are those experiments where the early environment of the subjects has been manipulated to examine its effect upon the mature organism's capacity to learn The results to date have been surprisingly definite, in nearly all cases the effects of restricting the environment in early life has been to depress learning performance when tested in later life

A typical series of experiments is that of Hymovitch (1952) Hebb had demonstrated that the rats blinded before reaching maturity were superior on maze problems This supported his thesis that an early injury may prevent the learning of some behavior patterns that an equally extensive injury, at maturity, would not destroy Physiologically, he would argue that some behavioral habits may require a large amount of brain tissue at their initial establishment but may persist when the amount of available tissue has been decreased 'The effect of brain damage in infancy is less selective and more generalized than such damages sustained in *later* life " Hymovitch reared his four groups of rats in the following controlled environments Group 1, rats with *early* (i e, 30–75 days) free environment conditions and *late* (i e, 85–130 days) stovepipe cage restrictions, Group 2, rats with late free-environmental and early stovepipe cage restrictions, Group 3, rats with both early and late free environment experience, and Group 4, rats with continual restriction to normal cages The number of rats in each group was only small, six or less, but the result of this study, and others of Hymovitch's studies showed clearly that the animals with the free environmental experience in early life were much superior at learning maze problems The effect of the *late* exposure to the free environment after confinement was negligible He concluded that the "effects appear to be relatively permanent and possibly irreversible," though this challenging statement is somewhat beyond the evidence

The Forgayses (1952) found that 26 day old rats reared in a free environment with playthings were at 90 days better at solving maze problems than litter mates reared in small cages without objects When the maze was rotated, the free environmental rats superior performance indicated their use of perceptual distance cues The authors conclude that 'the presence of playthings the most obvious agent of a direct transfer effect in the situation,' does benefit the animals but that the free environment also benefits performance and that this cannot be attributed to direct transfer Forgus (1955*a* and 1955*b*) reared young rats from 25 to 85 days in conditions where one group was exposed to a complex visual and motor environment and the other to complex visual but relatively simple motor surroundings At 85 days all rats were transferred to smaller cages for 1 week and then tested on an elevated eleven unit T maze After the animals had learned to run the maze making only one error or less they were then required to make their runs in the dark Forgus found that whereas the group which had been exposed only to the complex visual environment had learned quickly enough when the visual cues were present they were inferior in the dark to the group which had also had the varied motor experience He concluded that the "relative influence of early experience on adult cognitive abilities depends largely on the relationship between the kind of early experience and the requirements of the problem task"

Gibson and Walk (1956) in their study of young rats reared in cages with and without circles and triangles displayed on the walls were able to show that the visual experience in early life with the forms to be discriminated facilitated such learning even in the absence of differential reinforcement.

Woods (1959) in a recent experiment has widened the span of investigation He studied the effects of free environments upon rats which had previously proved to be inferior problem-solvers in the Hebb Williams maze due to their early restricted environments He used three groups E_1 always had a free environment, E_2 was restricted from 23 to 66 days of age and then placed in the free environment, and C remained throughout in the restricted environment E_2 at 66 days had markedly improved over the controls and was little worse than the E_1 group Further experiments of this kind investigating the longer term effects of early deprivation or enrichment should be particularly valuable for aging studies

At the end of their review upon the effects of early experience upon the behavior of animals Beach and Jaynes (1954) conclude that this influence is evident in three ways (1) habits formed in early life persist in adult behavior, (2) early perceptual learning affects adult behavior, insofar as early experience structures the individual's perceptual capacities, and (3) there are critical periods in development. This would imply there are specific stages in ontogeny during which certain types of behavior normally are shaped and molded for life The brief evidence we have cited would lend some support to the first two points, and we should have to turn to experimental embryology and comparative ethology to support the third

The importance of these hypotheses for

and over much longer time spans Of the issues which have been raised the gerontologist is most concerned with the following How persistent are early habits in later life? How far can they be modified? How general is the influence, or is it particular to some habits and, in some species, more pronounced with one sensory mode than another? What is the influence of later experiences where the individual has suffered early deprivation? Can such effects be reversed, and, if they can, how difficult is this to achieve? These and related questions bring out the desirability of further experiments along the lines of existing studies,

additional species should now be used and a longer time interval allowed to elapse between the early experiences and later testing So far the results of early experience have been examined with adult animals closely following the termination of the experience itself It would now be profitable to find out how far the effects would persist over the life span of the animal This problem is related to the further question of how far there are optimal periods in the life-cycle for the learning of certain habits This has been demonstrated in infrahuman species and in humans the inability of most individuals to modify their speech patterns and pronunciations after a certain age is widely recognized It is of course not necessary to be a scientist to observe this but the phenomenon suggests the possibility that there are other equally indelible habits which are intrinsic in the mental operations of an individual and of which the observer is not aware because he has not yet discovered the means of studying them The electrical activity of the brain may indeed prove to be as individualized and as stereotyped as the speech patterns when the techniques are developed to measure it

Résumé of Theoretical Constructs Employed in Aging Studies

The studies discussed in this section are an important facet of this general problem of how one set of experiences will influence future behavior Each of the four subjects —maturation degeneration transfer retroactive and proactive inhibition and the influences of early experiences—represents a different approach to this same problem and should be considered in this relationship In themselves they provide the nucleus for much further research Each is a reminder to the gerontologist interested in learning that he cannot study his subject *in vacuo* as something which is tacked on to the repertoire of the organism with little or no connection with what has preceded it Rather learning is to be conceived as a biological process in which certain periods and habits may well be of more significance than others Imprinting illustrates this in the life cycle of the young organism but it should not be overlooked that the parent too at this time is displaying a maximum sensitivity to its offspring

VII Short Term Retention and Recall

Much recent research has been devoted to an intensive study of one particular stage of learning an example of this approach being the experiments on short term retention which make up an interesting but elastic series of studies We shall consider these studies as being primarily devoted to the perceptual and initial assimilative stage of learning beginning with the time honored though often suspect immediate memory span

Immediate Memory Span

The usual procedure for measuring immediate memory has been to find out how many digits a subject could repeat after hearing them read at a steady rate Results with this kind of task do not correlate highly with those for other memory studies and considering the differences between them there is no reason why they should Gilbert (1941) reports a loss of 8 per cent for 60 year old subjects in digit span and a loss of up to 60 per cent for tasks such as learning a Turkish English vocabulary and paired associates The immediate memory task requires a subject to perceive each digit as it is presented to relate it to the previously presented material and to retain the whole until the time for recall Some recent studies have referred to this kind of task as though it involved no interference and have contrasted the results with other experiments where there were obvious sources of interference between the presented material which had to be retained and further competing responses But in the digit span experiment there is

every opportunity for interference, a subject is given say two digits which he is trying to retain while he is then presented with more digits which have to be combined with what he is already holding It would seem to be the interference with what he is holding that causes the span to collapse However some experimenters have argued against an interference hypothesis and have placed the major loss in immediate memory upon the rapid decay in the system (Brown, 1954 1958)

Short Term Memory

In discussing clinical studies of brain injury it was noted that the evidence suggested that the more recent the experience, the more vulnerable it was to environmental interference A further problem was raised with senile patients who frequently exhibit the feature of being able to remember a story or incident but are unable to remember that they have told the story only a few minutes previously In circumstances such as this there would seem to be a complete dissociation from the system which is satisfactorily retaining the long term events (the story) and any system which is registering recent events (the telling of the story) In normal circumstances an individual not only knows an event but knows that he has recently told it—though there is a tendency for all subjects to fail sometimes in this respect Senile patients break down here in a way that suggests the immediate ' registration system is somehow divorced from the longer term storage system Their forgetting that they have related a past memory seems to be the same defect that they exhibit with external events with the result that, though they can recall a past event they are totally inaccurate about when it occurred The initial perception would appear to be adequate, but there is a failure to pass on the percept to the system where it would normally be retained

This leads us to ask about the nature of retentive processes which follow immediately upon perception It is frequently hypothesized that such a system might be served by a neurological mechanism involving reverberating circuits This would contrast with longer term memories where a more permanent "trace" is established perhaps by structural or biochemical changes Psychological phenomena cannot throw much light on these kinds of speculations because they are as yet too imprecise to be amenable to verification In the case of the senile patients the fact that other long term events were being satisfactorily retained and that the initial percept was satisfactory might suggest that the failure is due to a ' transmission defect," the defect lying between the perception of the event, with its temporally related items, and its transmission to a longer term storage system But this could be merely a different way of describing what is implied by the reverberating circuit hypothesis There is no doubt that when incoming events are accompanied and followed by further events, there is a marked loss in what is recalled and the reasons for this are well worth investigation At the moment the brightest chances of success would seem to be in a further examination of the precise conditions under which the phenomena occur

Simultaneous Input

One fascinating series of studies has examined the ability of the organism to handle discrete signals which occur either simultaneously or in very quick succession (Broadbent 1956, 1957a 1957b) Where pairs of digits were presented simultaneously, one member of the pair to the left ear and the other to the right, subjects did not repeat them back in the pairs as presented but responded first to all the digits on one ear and then to all those on the other Thus if the pairs were 72, 15, and 36, a subject would respond with either 713256 or 256713 but never in the pairs as presented Subjects found it difficult and made mistakes when they tried to alternate their responses between the two ears The

same finding was established between simultaneous messages for the ear and the eye

The experiments illustrate the limited capacity of the human perceptual system and the need for some selection of inputs if the system is not to be grossly overloaded Broadbent (1957a) has suggested that selection is achieved primarily by a temporary storage stage occurring previous to the selective operation Where information is held too long in such a store it decays rapidly and is soon no longer recoverable With such a simple system it is possible to explain a number of experimental findings but of course this does not exclude other possibilities Welford (1958) has pointed out that though we do not know the precise nature of the impairment to short term memory with age there is evidence to suggest that it is increasingly liable to interference by other activities as age advances The experiments which he quotes—Kay (1953) and Kirchner (1958)—involve complex tasks n which subjects were receiving signals and during the same time interval preparing responses to previously received signals Older subjects in these circumstances were unable to recall the correct responses and their immediate retention certainly suffered Insofar as in normal learning situations the perceiving and immediate retention of material has to take place against a similar background of further mental activity this vulnerability in older subjects would be most significant

This would seem to be an area of expanding research The subject is linked with those studies of skilled performance which have stressed the significance of the transmission of s gnals and have brought out the limitation of the human organism as a transmission system That system is limited both in channel capacity and in the number of channels which can be used simultaneously often exhibiting the features of single channel transmission where the information conveyed by the signal is at all high (Davis 1957) These are limitations which the individual overcomes by learning the probabilities of events in his environment and consequently making a highly selective and skilful perception of stimuli We cannot say as yet how far age does or does not influence channel capacity (cf Crossman and Szafran 1956) But we can say that irrespective of age a major difficulty arises when a subject is required to *alternate* quickly between different streams of information Events which might be satisfactorily received from one source may prove too many if coming from two The same difficulty arises if the alternation is between perceiving responding and then perceiving again The system is slow to change from one operation to another or since it is again respectable to say it to change the focus of attention

Abstraction of Material

In the study of immediate and short term memory the usual material has been digits consonants nonsense figures and sentences These have called for verbatim accuracy with the task allowing the subject no opportunity for summarizing the presented material While verbatim accuracy is a legitimate demand much of the retention of everyday life is not of this kind but as with perceiving is a more selective process of what is considered by the individual to be important Some studies have attempted to examine short and long term retention where the individual could not always learn to complete verbatim accuracy and have illustrated how a subject when presented with such material makes a perceptual analysis of its salient features (Kay 1955 Gomulicki 1956) This abstractive process at the time of perception is primarily dependent upon the subject s ability to comprehend the material to this extent it is a variation on the Bartlettian theme of an effort after meaning and might be treated as a transfer phenomena It is of particular interest to aging studies It is known that older subjects when presented with material do attempt to make an interpretation of it and it would be worth

while to find out how far their assimilation of material differs when they are able to make such an abstraction and when they cannot follow this procedure With familiar material older subjects may not show anything like the same deficit as they do with unfamiliar There are no studies of this kind as yet Gilbert's (1941) being the nearest to it she used a variety of tasks and found differences between them but these were for verbatim learning What is required is a study examining the initial assimilation of material in additon to the rate of progress which is made on the road to complete mastery

Recall of Material

It is not necessary to demonstrate experimentally that an individual may be "remembering" material which he cannot recall, every experimenter has been his own subject for this study One of the more revealing features of this state is discussed by Broad (1925), who points out that, with "negative memories" we can, paradoxically, say what a thing is not when we cannot say what it is The psychologist is accustomed to think of these oscillatory states in terms of threshold and this concept may be usefully applied to recognition and recall processes (Kay and Skemp 1956) These thresholds can be experimentally manipulated in terms of the induced set or attitude of the subject, and current statistical procedures such as information theory allow us to make neat measures of the number of alternatives in such situations and to compare the uncertainty with which a subject is faced (or in other words, the amount of information a particular signal will be carrying in a given situation) This of course is only one of the variables influencing recall, but by working within the same range of material and manipulating the number of alternatives from which a subject has to recall or recognize an item, it should be possible to plot such thresholds for young and old subjects with some reliability, and the differences, if any, both interindividual and intertask, would be revealing of particular difficulties

If proposed theoretical systems are to be experimentally examined, there is a need for more exact work of this kind For example the concept of signal to noise ratio has been discussed by Birren *et al* (1954) and by Gregory (1956) for visual thresholds As yet this could be applied only as a helpful analogy in recognition studies, the model being of the kind that a subject trying to recognize an item in a context of many items has to detect a particular neural signal in a context of multiple signal activity—neural noise If we ask what are the likely components making up such "noise," a plausible suggestion is that they are the signals from the known events presented in the experiment and the relatively unknown events of the subjects' previous experiences Neural firing from such events would make up the background signal strength from which the particular signal had to be selected The greater such background activity the harder the problem of detection But it should be observed that, insofar as much firing would be arising from those events stored in the nervous system, it would probably represent *patterned activity* rather than random firing Such patterns of neural firing may be an extension of the engineer's concept of "noise" but would be legitimate insofar as such activity is irrelevant to the task in hand It will be noted that signals are not being lost, they are being "blocked' by the persistent activity of other signals In such a system, then, the task is to measure whether the signal can or cannot be detected, and two obvious variables governing that process are (1) the strength of the signal itself and (2) the strength of the background interference "noise' arising primarily from the stored experiences of the individual These patterns of signals not only interfere with the detection of the desired event but give rise to repeated iden

tification of the wrong signal Curiously enough, this phenomenon of repeated mistakes rather than randomly fluctuating errors is a marked characteristic of older persons learning (see below, "Repetition of Mistakes")

VIII Recurrent and Unsettled Issues for Aging Studies

Measures of Learning

There is no one measure of learning, and it is unlikely as long as we are relying on stimulus and response phenomena that there ever will be There may be many stages in the learning process but very few experimental studies concern themselves with measuring more than the last—whether the response is changed as a result of practice Such measurements have been made in a variety of ways ranging from an all or none measurement of whether the response does or does not occur to recordings of its amplitude latency frequency and resistance to extinction The diversity of measures has followed from the diversity of the methods of studying learning In aging studies an older group is generally being compared against a younger group or against some standard measure but the latter cannot often be used The procedure is restricted to comparing one group against another group on the same task and even at this level it runs into difficulties It is not enough to know the final score on a learning task, with which some experiments have been content for while it is useful to have the data that different age groups reach the same criterion in the same or in a different number of trials etc this may be misleading as to their manner of learning To this extent the rate of learning is a much sounder measure Skinner (1953) has been foremost in advocating such a measure of acquisition and extinction achieving in the near environmental vacuum of the Skinner box results of exceptional stability and consistency There is no doubt that Skinnerian techniques would often provide the gerontologist with a most useful yardstick In the same way as the clinician is using Skinnerian methods to provide some basic behavioral indexes with which to compare his studies involving ablations and electrode implantations, so the gerontologist could profitably use them in comparing the learning of older and younger subjects

Method of Common Points of Mastery

By securing a continuous record throughout the course of learning, Skinner's rate of responding measure would throw some light on the further problem of the variance which is brought into learning studies when different groups may begin and end their practice at different points on the learning curve Thorndike (1928) proposed in his method of common points of mastery to use two points one in the initial and one in the later stages of learning, which were common to all compared individuals The rate of learning for all subjects would then be compared by measuring the number of trials or responses required to pass from one common point to the other Such a method would therefore compare rates of learning over the same "stretches" of the learning task, since all subjects were passing between the same two points But the method depends for its validity upon a verification of the same query with which it was trying to cope As Ruch (1933) pointed out, one subject may have reached the initial point of mastery through the hit or miss progress of everyday life, and another may have reached the same point only under the immediately preceding experimental conditions, but the validity of Thorndike's method would depend upon knowing that under such circumstances the form of the two learning curves would be identical, other things being equal If they would not, then the comparison would be based on wrong premises

COMPARING DIFFERENT KINDS OF TASK

This problem raises the query of under what circumstances it is legitimate to try to compare learning performances of old and young If two learning curves are not of the same form does it imply that the two processes are different? Alternatively if certain sections of the curve are matched and if there are differences for the remainder how far can it be concluded that the processes are the same? Such queries all point to the need for as full and continuous a record as possible Skinner box procedure would provide this but it would not lend itself to those learning tasks where the response is neither unitary nor simple as in serial motor skills It would seem that comparisons of this kind will be most forwarded by the approaches which are being developed from the mathematical concepts which have already been mentioned It is one of the attractions of such studies that they have tended to cut across traditional psychological demarcation lines and have compared conditions which previously have not been brought within the same compass Information theory has attempted to examine whether under a variety of different conditions the human system does handle much the same amount of information While it has been shown that there is some consistency within a category of tasks such as serial motor or visual perception there have been marked differences between the categories This has complicated the rate of transmission concept in particular involving the experimenter into speculating upon the units which the human system employs to code various types of task Man does not always behave as a simple predictive model but it is the virtue of the information theory analysis that it is sufficiently precise for the experimenter to state where behavior does and does not conform to prediction For this reason it is to be hoped that some of these techniques might be used in aging studies for they lend themselves to experiments which state precisely the similarities and differences between groups An illustration of this would be the analysis of the information capacity of young mental defectives by Annett (1957)

Variation

INTERINDIVIDUAL

One of the most widely accepted effects of aging upon learning is the enormous range of variation which is always found It is possible to say with some certainty that in a representative learning task the majority of an older group will show some decline for one reason or another but not to say which individuals will or will not make up that majority group As further attempts are made to analyze the particular stages of learning which present difficulty to older people the reasons for this interindividual variation may become clearer Studies with other mental processes such as the Foulds and Raven vocabulary scores (1948) have brought out how the individual variation increases with age the initially low scorers showing marked decline while the highest scorers improve slightly

INTRA INDIVIDUAL

Within the same individual the evidence is quite inadequate It is customary at this point to say a few hopeful words about longitudinal studies which have been praised in principle as often as they have been neglected in practice Certainly longitudinal studies particularly with lower organisms would provide some important answers though the studies with humans

in such studies as those by Owens (1953) and by Kallmann (see chap viii) With learning studies it would be a most useful immediate step to examine subjects intensively over a range of tasks so that the variation in the individual might be scrutinized If adult learning does depend so much upon acquired habits and experiences

then the variation within the same older person for different tasks is likely to be greater than for a younger individual

TASK COMPLEXITY

The significance of this variable in producing variation in results is now being studied (Birren and Botwinick, 1951, Birren *et al*, 1954, Clay, 1954) In any multistage or serial process the task can be made easier if the load at one point where it is heavy can be partly shifted to one where it is light Inflexible tasks, such as some paced operations, which do not allow this degree of elasticity are the more difficult for this reason Where tasks involve a series of relatively simple stages, the individual can adjust them to his own requirements, and any difficulty at a particular point may be totally obscured in the final end score But, as the task complexity increases, such intratask adjustment may not be possible, with the result that the whole task collapses and that there is an apparently dramatic breakdown Thus individuals who may score highly at an easy stage of the task fail completely at a more difficult (e g, Birren, 1954, Kay, 1954) There are examples in aging experiments where different results have been attributed to assumed differences in psychological processes, but it would appear that often what is in fact contributing to the discrepancy in the results are the very different degrees of difficulty of two tasks

LONG TERM EFFECTS OF MOTIVATION

Some of the problems of motivation have already been discussed One further aspect is peculiar to aging studies and would seem to be based upon the everyday observation that older people do not try to learn something because they are not interested in it The implication is that they could be successful if they wished Certainly, older people are more selective in their range of interests This raises the problem as to what the long term effects of motivation are If an individual in everyday life is unwilling to learn new operations, does the ability to do so remain unimpaired? "Could he do it if he would?" It has sometimes been assumed in discussing these long term effects upon a biological organism that there is one variable, motivation, which may or may not be brought into action upon another variable, learning, which remains unmodified through time But this seems unlikely in an adaptive biological process The converse would be to argue that, if there is a prevailing lack of motivation to learn unfamiliar things, this may bring about a decline in learning ability, such a loss in its turn contributing to a further decrease in motivation, which in its turn causes a further decline in learning, and so on On this view the organism, which perhaps through an original lack of motivation discontinued a particular course of action, faces a present situation with a definite loss in learning ability If we ask whether motivation could raise a performance to its previous level, the answer would seem to be that it could not Experimental evidence is lacking here to clinch the argument, since in the cases where performance has not improved it is generally possible to argue that insufficient is known about the motivation of the subjects But it is of note that in other fields, such as that of physical sports, there are innumerable examples of older contestants who, having once allowed themselves to go out of training, have been unable with "all the will in the world' to achieve their former standards The break in their routine brought about a genuine loss in their ability, which is not to be reversed by boosting motivation It would seem, then, that in aging studies, where we are dealing with the long term effects of motivation, it is well to remember that a biological system does not operate in reverse It is natural enough that we should try to say why an ability is what it is found to be by attempting to disentangle some of the contributory factors, but we have to accept the product as representing a relatively stable state of the organism

Speed of Learning

It is a commonplace that older individuals are often slower than younger in a variety of tasks such as intelligence testing and motor skills and in learning The question is whether this tardiness can be attributed to any one particular stage of the process Human learning has been characterized as being slow at the beginning of life but accelerating thereafter as the new is related to the already learned, this is Hebb s point, and Snoddy (1926) was distinguishing much the same feature in his adaptation and facilitation stages Older subjects are likely to benefit insofar as they possess an extensive repertoire of learned habits for, the wider the range the greater the possibility of it legitimately encompassing another situation But learning however ill defined implies adaptation at some point that is, to be recognized as requiring learning, there must be a difference either in the stimulus situation in the response or in some relation between the two Where the repertoire of already learned perceptions and responses is large, the danger may be that the new situation is distortedly related to the old The significance of this assimilative stage of learning for older subjects has already been emphasized, especially under time stressed conditions (see above, "Aging and Perceptual Theories")

REPETITION OF MISTAKES

On the other hand, the speed of learning is also determined by the persistency of mistakes In mental activities, including recognition, learning, and problem solving, an indication of difficulty is the repetition of the same error response The learning of older subjects is frequently so characterized (Kay, 1951, 1954) The question is not whether the phenomenon occurs but why It might be argued that, if the same response, right or wrong is repeated, the organism is retaining something, since this is more than a random guess Against this the contention would be that the individual is not remembering the response as such but at each presentation is assessing the probabilities *de novo* and, being consistent, continues to arrive at the same response This latter, however, is not the whole story Wright (1957) has shown that individuals are consistent with the mistakes which they have built up *in the course of* the learning task, and it is known that, when subjects finally correct their repeated errors, they have learned not only the correct response but the error in which they persisted It would appear, then, that in many instances a subject makes his original response on the basis of his own predilections and thereafter has difficulty in amending it to accord with further evidence In these circumstances the bar to progress is not so much the absence of knowing the correct response as in ' knowing" the wrong This point that progress is not barred by blankness but by wrong solutions is perhaps more obvious in examples from other fields, say that of motor skills Individuals in their activities of walking, running, and carrying out tasks involving eye and hand co ordination make a series of extremely consistent actions Many of these could be labeled "wrong ' in the sense that they are maladaptive, in games an example would be a tennis player who always plays a stroke in a particular style which he is well aware prevents him from executing a good stroke but which he appears "unable ' to correct It would seem that the habit pattern which has been built up makes it so much more difficult to establish the correct sequences

In trying, then, to assess the difficulty of learning a task, it is necessary to take into any one individual may bring into the situation In some tasks where these individual probabilities happen to be correct, they may lead to quick learning, and, conversely, where they are not, they may seriously

impede progress An older subject facing any task with a varied and well established repertoire of response tendencies is vulnerable on either count

IX CONCLUSION

This chapter has been concerned with the interaction between learning theory and aging phenomena Such interaction is more a pious hope for the future than a matter of recordable history On the one hand, learning theory, as it has been traditionally discussed, has been concerned with a narrow range of events, generally associated with animal conditioning and learning experiments On the other, the gerontologist has been interested in the broad range of human behavior and has been primarily occupied with exploring the "dimensions of variation" in learning situations, such studies playing a part in providing the necessary data, of which there is still an insufficiency

The attempt has been made to indicate that the accepted demarcations of learning theory exclude much that might be expected to come within its purview and that, within this excluded material, some of which is recent and some long neglected there are many theoretical concepts of particular relevance to aging studies On the gerontological side, those theoretical speculations which have been put forward to explain aging phenomena have often been used somewhat enigmatically and with a lack of tightness in their argument The tenuous connection between learning theory and aging studies mentioned in the introduction was perhaps inevitable in the initial stages, but, insofar as progress in other areas of learning research has indicated the significance of certain variables, it would now seem profitable if some aging studies were conducted in relation to them By way of summarizing the issues which have been raised, the following appear to be the most pertinent for the gerontologist interested in learning theory

STUDIES ON SHORT TERM MEMORY

In this area the input can be precisely controlled and any variation in the response accurately measured These studies allow the use of a variety of experimental material, from the presentation of letter or digit symbols to motor skill tasks and are not restricted to any one sense modality The findings are often as applicable to perceiving as to learning It is a field cutting across traditional lines and in which many of the newer techniques of analysis are appropriate

SPEED OF ASSIMILATION

In some respects this is a subsection of short term retention studies But in its own right the problem of the rate of input transmission is a key issue in aging Again it may involve a variety of tasks, including non symbolic material, as in motor skills, symbolic transformations, and the sensory input from all modalities

INFLUENCE OF ENVIRONMENTAL EXPERIENCES, EARLY AND LATE IN LIFE

The increasing evidence of this field could be supplemented with studies which examine how permanent are the effects of such early experiences over the life-span of the organism and whether such effects can or cannot be reversed These studies might also throw light upon the accuracy of long-term memories

ABILITY TO MODIFY EXPERIENCES

This is one of the central problems for older subjects To the mature organism the input is becoming less and less important. There is a relative depreciation of the value of the stimulus, as events become more predictable While this has many advantages in the familiar environment, it presents problems in the unfamiliar So much learning for an older subject represents a modification of existing experiences rather

than a reaction to a totally new situation Here often learning involves unlearning, and this inability to modify responses classed as rigidity and resulting in continuous error repetiton is a hallmark of slow learners It would be pertinent to examine the repetition rate of older subjects in a range of learning tasks

TRANSFER

This of course is involved in the modification of experiences but in view of the many different attributes of the term it would seem that its influence upon aging might best be studied under such heads as 'stimulus generalization and differentiation proactive and retroactive influences and the role of practice in maintaining learning ability While such researches involve a range of tasks they do lend themselves to detailed and systematic manipulation of the selected variables

NEUROLOGICAL ISSUES

Present investigations using micro electrode implantations upon the influence of subcortical structures on learning suggest that the sensory input is relayed to different areas and involves different pathways after learning has taken place In view of this alteration in the functional relations between areas it would be valuable if such studies compared older and younger animals, particularly in the speed with which such functional connections were established

MOTIVATION

Differing degrees of motivation may be responsible for slow learning exhibited by some older animals In view of the importance of this issue a more direct attack is indicated, such as represented by the studies upon the role of the ventromedial nuclei of the hypothalamus in regulating eating behavior

CLINICAL

The phenomenal data from these studies especially from the amnesic syndrome, have provided illuminating evidence upon retentive functions, some features of which are closely related to what is found in senile cases and in normal older subjects These relationships might be systematically examined

Several of the above issues could profitably employ animal studies It is a practical point that of all possible subjects which are available to the experimenter, the aging populations of animal laboratories are far and away the most accessible Such animals could be used extensively, provided normal records had been maintained on their previous histories As a further step toward meeting the criteria of control and repeatability these aging studies might make a wider use of existing techniques and procedures of animal experimenters

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XIX

Age and Learning—Experimental Studies

EDWARD A. JEROME

I. Introduction

In its subtle but persistent fashion society has for millenniums been molding and remolding a tantalizingly amorphous stereotype of the aged individual (Richardson, 1933). Among the notions stressed in this distillation of popular experience is the belief that, as the individual progresses from early maturity to old age, his mental faculties deteriorate, especially his ability to learn and to remember. These alleged phenomena of deterioration have, moreover, been given a quasi explanation by representing them as the natural concomitants of the more pervasive necessity for degeneration of all biological materials as a function of time. Thus, by its own inevitable disintegration, the physiological organism, as the mechanism of behavior, necessarily entails an impairment of the behavioral faculties that it implements. Thorndike *et al.* (1928, p. 131) put the matter quite simply: "There can be little doubt that at some time between twenty and ninety the inner developmental forces which made the ability to learn wax give place in most persons to other inner influences which make it wane." With somewhat greater specificity Ruch (1934, p. 284) says: "From the biological concept of senescence as a condition of lowered plasticity of tissue and the further assumption that learning involves change in nervous tissue, it was hypothesized that old age should bring a differential deficit in learning ability as a function of the amount of re-organization of pre-existing habit patterns required in learning."

One of the functions of science is to test such socially significant notions by designing and creating situations that provide an opportunity for the occurrence of observations that are patently inconsistent with them. It is the purpose of the present chapter to review some of the results of such confrontations of the belief that memory and the ability to learn deteriorate after maturity and that such deterioration, if it occurs, is to be explained on the basis of a general biological degeneration resulting from prolonged functioning of the physiological mechanism. In this connection it is also worth noting, however, that the notion in question simply asserts that every organism, as a result of persisting in time, sooner or later after maturity suffers a loss in its ability to learn. It is not indicated whether this loss is gradual and continuous or abrupt and discrete. The change is not assumed to progress at the same rate or in the same manner in different individuals. It is not clear to what extent the rate and manner of loss is determined by the particular constitution of the individual or to what extent it is dependent upon the accidents of the environment or the epoch in which the individual happens to pass the interval that presumably defines its age. Although these considerations are unessential to the hypothesis as it is usually stated, surely they appear worthy of empirical clarification and should be kept in mind in connection with questions of methodology

II Methodology

Before presenting the experimental results that constitute the principal subject matter of this chapter it seems desirable to discuss and illustrate some of the problems of methodology that have been identified during the brief history of research in this field Just as it would be unreasonable to expect the pioneer workers to have anticipated all or even many of the ambiguities that ultimately became associated with their results it would probably be unduly optimistic to expect a reader to profit fully from these considerations without a preliminary review of the critical evaluations that have appeared necessary over the subsequent years

RELEVANCE OF DATA FROM INFRAHUMAN SUBJECTS

There are several good reasons for employing data obtained from observations on lower animals for the purpose of testing the hypothesis of cognitive degeneration The most cogent of these derives from the fact that it is obviously intended to hold independent of phylogenetic status and so extensive a generalization cannot be received with conviction until it has successfully withstood thorough testing on an adequate variety of organisms Moreover it will no doubt have been noted that the biochemist neuroanatomist and physiologist in their search for signs of the allegedly universal biological degeneration have confined attention very largely to infrahuman organisms and have thus created an important fund of knowledge directly relevant to lower animals The problem of discovering and testing the behavioral implications of this work can of course be most appropriately pursued by performing the logically indicated psychological studies on similar organisms Then and perhaps somewhat less abstract than either of these considerations, there is the fact that the controlled observations necessary for scientifically satisfactory inference frequently expose the experimental materials to marked discomfort or even the risk of serious trauma Many logically indispensable experiments are, therefore, performed on lower animals simply because it would be impractical to perpetrate them on man Finally the practical considerations of convenience and expedition render it attractive to use, for such studies small short lived animals that do not require complicated attention to maintain them in health and apparent contentment Thus although it is quite clear that most, if not all of the interest in the effects of age on the ability to learn is anthropocentric in origin, studies on infrahuman organisms have been included in this review because of their systematic and heuristic importance in connection with this problem

LONGITUDINAL AND CROSS SECTIONAL METHODS

In longitudinal studies individual performances are evaluated at selected intervals with the intention of detecting whatever changes may occur in these performances during the course of the experiment In cross sectional studies the performances of the members of several different groups are evaluated usually on a single occasion the groups being selected to represent age samples of some population at a particular epoch and to cover some arbitrarily selected range of ages The purpose of the experiment is to evaluate the differences that may exist between the groups with respect to the performances tested

It is of course, immediately clear that there may be great differences between age groups that probably should not be regarded as causally related to the aging process Thus differences in culturally sanctioned reaction tendencies, relevant past experiences and educational background any and all of which may strongly influence performance on a variety of tasks appear to be related more rationally to the epoch and particular social structure in which the individual was born and reared than to any biologically determined process

of aging per se It must be anticipated that the cross sectional method will reflect these differences between generations in such a fashion as thoroughly to confound them with any genuine effects of aging that may be present The longitudinal method, on the other hand, is especially adapted to the investigation of intra individual changes and might well permit to pass unnoticed differences between generations

It seems quite natural then to inquire why, in spite of its obvious superiority in logical directness and analytical power, the

parent anomaly, especially insofar as studies involving human subjects are concerned Not only do such investigations require an imposing amount of financial and organizational support but they are also singularly unattractive to the individual investigator, who can hardly expect to survive a study which he undertakes even quite early in his career It is fortunate therefore that the cross sectional design though essentially inconclusive with respect to aging has the property of facilitating the identification of areas in which the probability of the operation of an aging effect is low This follows

to uncover differences between generations Thus if a cross sectional study fails to reveal generation differences in connection with a given faculty, it is unlikely except for the possibility of compensatory factors, that this function is sensitive to the processes of aging On the other hand if a cross sectional study does reveal marked differences between generations it is possible that the faculty under test is highly susceptible to the effects of the processes of aging It seems therefore, that the cross sectional design has a very definite value as an exploratory device that can be employed to identify areas of investigation that have promising prospects

MOTIVATION

The impression that one receives from reviews of the literature on the relation between degree of motivation and rate of learning (Hovland, 1951, McGeoch and Irion, 1952, chaps vi and vii) supports in general Stone's (1929*a*, 1929*b*) notion that good learning goes hand in hand with high motivation More detailed consideration of this relation, however, suggests that it is extraordinarily difficult to disentangle the two factors, since in some cases, at least, motivation appears to be acquired (Brown, 1953) and since learning, or at least working at some learning tasks, appears to be rewarding in itself (Harlow, 1953) Finally, some of the empirical evidence on the relation between degree of motivation and rate of learning is far from being unequivocal (see, e g, Denny and Davis, 1951, MacCorquodale and Meehl, 1951, Gilchrist, 1952, Kanner, 1954) Clearly, additional information is needed on the extent to which learning rate is determined by the level of motivation Moreover, for the purposes under consideration it would be desirable to know to what extent the relations between degree of motivation and learning rate are different at various age levels

The belief that older organisms are more difficult to motivate than younger ones is a rather frequently recurring notion (Anderson, 1956) that was given prominence by both Stone (1929*a*, 1929*b*) and Thorndike (1928) Stone was apparently brought to this conviction by observing a great difference in the amount of activity emitted by his younger animals as contrasted with the older ones during their performance on a latch escape problem He adopted, as a routine procedure, a system of differentially depriving his hunger motivated animals in such a fashion that the younger ones were allowed to gain slightly, while mature animals were maintained at a predetermined low weight and older ones were deprived to the point of losing slightly throughout the experiments

Margolin and Bunch (1940) have used

performance in the Columbia Obstruction Apparatus (Warden, 1931) to compare rats of various ages with respect to their sensitivity to various durations of food deprivation The test consisted of observing the number of times that animals crossed an electrified grid in order to secure food after various degrees of deprivation A diagram of the apparatus is shown in Figure 1 together with a brief explanation of the standard procedure There were 720 rats divided into three age groups, 30–35 days, 150–75 days, and 300–350 days Each of these groups was divided again into twelve subgroups in order to administer four levels of shock with each of three deprivation durations Because the youngest animals apparently could not tolerate the longer deprivations they were not given the same schedule as the other two groups The results of this study are summarized in Figure 2 in terms of the average number of grid crossings in 30 minute test periods The data from the several shock intensities have been combined in this presentation because none of the groups reacted to differences in shock intensity

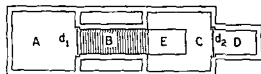
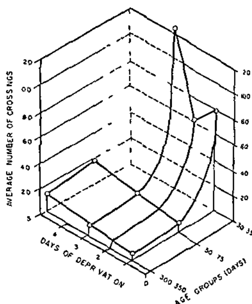


FIG 1 —Columbia Obstruction Apparatus The test animal is placed in compartment *A* and a trial is started by rasing door d_1 manually to permit entrance into the obstruction compartment *B* the floor of which is an electric grid *E* is a release plate which operates door d_2 automatically when the animal enters the incentive chamber C which gives entrance to the incentive container *D* After exposure to the incentive the animal may be returned to compartment *A* to begin a new trial (After Warden 1931)

Figure 2 shows the average number of crossings (vertical distance from the *x y* plane) as a function of both age and duration of deprivation separately For all age groups the rate of crossing increased as a function of the amount of deprivation, indicating that deprivation was, in fact, an activator This relation was very much more marked for the youngest animals than in either of the older groups Similarly, for any given degree of deprivation, the rate of crossing was inversely related to age, indicating that any given duration of deprivation had less effect on the older animals Although these results are definitely in agreement with Stone's position, it seems important to observe that the big age difference in reaction to any amount of deprivation occurred between the first and the sixth month of life and that the change from the sixth to the eleventh month was much less impressive for all deprivation



durations of food deprivation (Adapted from Angolin and Bunch, 1940)

durations This fact is emphasized in Table 1, which shows the percentage decrease in the number of crossings per 30 minute test during the two age spans mentioned Clearly if this indicated deceleration of the affected by age between late maturity and early senescence, and this is especially true

for the most commonly employed deprivation, 1 day

Unfortunately, the results of this experiment are unsatisfactory in several aspects for the present purposes (*a*) the reaction to various shock intensities and no shock was disappointingly unsystematic, (*b*) in the 30-35 day old group there was a marked inversion of the first order on one (2 days deprivation) of the three points on the deprivation function in spite of the fact that each point was based on the average performance of 80 animals during a 30 minute work sample, (*c*) although the equal deprivation contours showed satisfactory consistency, it is impossible to secure a convincing impression of the form of the function relating output to age because there are no data points over the range in which the rate of crossing changed most rapidly, and, finally, (*d*) it does not cover the age range most pertinent to gerontological interests (i e, from 1 to 2 years)

Notwithstanding these ambiguities, taken in conjunction with Stone's rational analysis and some additional observations by Ivy (1952) and by Carlson (1916) to the effect that hunger contractions are more frequent and more persistent in younger than in older dogs, the results of this experiment must be accepted as justifying grave misgivings in connection with age comparisons of learning ability that employ hunger motivation without any adjustment for possible differences in its effectiveness as an activator in the different age groups Moreover, this question has recently acquired a somewhat intensified importance with the appearance of Verzar-McDougall's (1957) study, in which a marked decrement in learning ability was found to be associated with age when *differential deprivation* was not employed Up to this time, Stone's very extensive work in which no such decrement was found when differential deprivation was employed had remained unchallenged It seems abundantly clear that there is need for a thorough investigation of the effects of age on the relation between incentive conditions and motivation before any firm opinion can be formed concerning the relevance of animal studies employing hunger drive

In view of the important functional relations apparently existing between motivation and speed of learning, on the one hand, and between motivation and age, on the other, it seems that progress in the understanding of the relation between learning ability and age is predicated upon considerable prior clarification of the relation of both of these factors to motivation Although the motivation learning relation can safely be left to general experimental psychologists, at least within a narrow age range, it seems that the gerontologist will have to accept responsibility for investigating the motivation age relation This seems to be a topic that has been neglected over the range of gerontological interest in both animals and man

TABLE 1*

PERCENTAGE DECREASE, OVER TWO AGE INTERVALS, IN THE ACTIVATING EFFICACIES OF SEVERAL DURATIONS OF FOOD DEPRIVATION†

Days of Deprivation	From 1 Month to 6 Months	From 6 Months to 11 Months
1	94	14
3	90	40
5		35

* Source Adapted from Margolin and Bunch (1940)

† Indexes are based on the total number of crossings during a 30-minute test in the Columbia Obstruction Apparatus at each of four shock levels

SAMPLING

The problem of selecting groups of subjects borders on the baffling in the cross sectional method, because its purpose is to supply some reason for believing that the "age groups" do not differ systematically in any relevant respect except in age Some experimenters have, indeed, exhibited great

ingenuity in this direction Miles (1933) and his collaborators, for example, were able to induce the mature and aged members of the families of many of their younger subjects to serve as the experimental subjects in some of their studies This control was intended to minimize the effects of such factors as genetic background, socioeconomic status and educational level It is of course difficult to estimate how successful even this maximum effort was, for it fails to control for the multitude of factors included under the heading of "cultural drift' due to improvements in the educational system and the technological developments within society

Thorndike (1928) when not using the fairly homogenous sample constituted by university students was careful to partial out the influence of intelligence and verbal facility Ruch (1933) on the other hand has pointed out that performing an age study at a fixed educational level introduces a systematic error because it is to be assumed that the older subjects at the chosen achievement level are less intelligent than the younger ones Although he applied this principle at the level of primary and secondary schools it is not clear that it would not be applicable to some degree at least, to college and graduate students

In the longitudinal method the sampling or selection of subjects is not intended to supply a control that is felt to be necessary for an interpretation of the data as reflecting an age difference Its principal function is to secure a sample population that will be judged sufficiently unbiased to provide a, basis for generalization or on the other hand that is sufficiently restricted to permit conclusions concerning a specific segment of the population in which interest happens to be concentrated Thus insofar as the longitudinal method is concerned, selection does not have the special function of providing an *inferential basis* for conclusions concerning the effects of age but merely its typical function, that of achieving representativeness

INITIAL AND FINAL ABILITY

Ruch (1933, p 389) describes the difficulty arising in this connection in the following statement 'The comparison of young and old learners with regard to absolute learning ability is rendered peculiarly difficult by virtue of the fact that initial ability often varies with age and the task

Thorndike (1928), who apparently discussed the problem originally, employed two devices to adjust for this discrepancy The first, the "method of common points,' is most likely to be usable when only two groups are being compared and consists essentially of considering only that portion of the results between some point of coincidence in the data from the two groups and the point of mastery or the termination of the observations Ruch (1933) suggested that this procedure can be justified only by a demonstration that the rate of learning between such a common point and mastery is independent of the rate at which this point is approached He has also provided (1936) an exposition of the variations available with this treatment Thorndike's (1928) second technique for dealing with the difficulty of 'initial level' was the method of partial correlation by means of which statistical control for different initial abilities can be achieved The modern analogue of this device is the multivariate analysis of covariance employed by Gladis and Braun (1958)

It seems probable that the principal objection to disparities in initial abilities derives from the likelihood that they are due to differences in transfer, positive or negative, from experiences predating the learning test in question and as such should not be permitted to influence indexes purporting to reflect differences in modifiability in general

An example of the type of confusion that can arise in this fashion may be taken from a group of experiments reported by Ruch (1934) Two studies were performed with an adaptation of the Koerth rotary pursuit apparatus The subject's task was to keep a

stylus in contact with a small conducting area on an otherwise insulated turntable which rotated only when such contact was maintained The score recorded was the total number of tenth revolutions made in twenty five periods of thirty seconds It should be pointed out that scores of this type are influenced by the initial ability of the subject as well as his rate of improvement' (1934, p 269) Another experiment, identical with this except that the subject could see the apparatus only through a mirror, was performed to provide a high interference comparison The data in Table 2 were culled from Ruch s Table 15 (1934 p 277) The entries are the average number of tenth revolutions for three age groups young (12–17 years) middle aged (34–59 years), and old (60–83 years)

According to Ruch, 'The younger group excelled the older group more in the mirror vision than in the direct vision rotor learning' (1934, p 278) These data, however, do not justify the conclusion that learning took place in any of the groups under either of the conditions, because they provide no evidence that there was any increase in the number of revolutions per trial from the beginning to the end of the practice series It will be observed that the difficulty of interpretation arises, not so much from the fact that there may have been differences in the initial abilities of the several groups but from the fact that such differences, if present could not be evaluated because of the method of recording the results Thus no adjustment could be made for them, and they became confounded with measures of an improvement that could not be shown to have taken place because of this confusion

Current practice seems to consist in securing measures of gain relative to initial ability, or of rate of improvement during the practice trials, though it is not clear that any generally accepted method of dealing with the problem of initial level has become available or, yet, that there is any considerable agreement among experimenters as to its importance, providing, of course, that confounding of the nature described above is avoided

SPEED RELATED INDEXES

The belief that age brings with it a marked slowing down of performance in a wide variety of tasks is, at the present time, probably one of the most strongly substantiated notions concerning the psychological effects of aging (Birren and Botwinick 1951 1955*a*, 1955*b*, Botwinick and Shock, 1952, Birren, 1955, Botwinick *et al*, 1957) It is to be anticipated, there-fore, that, in learning experiments that employ time related indexes of mastery or improvement (e g, total time required to reach a criterion), the older subjects will be found distinctly inferior to younger ones Against the notion that such results do not necessarily reflect an impairment of learning ability *per se*, it can be argued, of course, that this temporal aspect is a very important part of learning—that the total time required to master a task and the ability to increase the rate of output to a maximum are of great practical value It should be possible to concede this and still hold that there are other important considerations involved Although explicit investigation of the pervading influences of the speed deficit on learning is undoubtedly of great practical significance, failure to

TABLE 2*

AVERAGE NUMBER OF TENTH REVOLUTIONS MADE IN TWENTY FIVE 30-SECOND TESTS ON A ROTARY PURSUIT TASK BY THREE AGE GROUPS UNDER TWO EXPERIMENTAL CONDITIONS

Age Group	Direct Vis on	Mirror Vis on
Young	2857	772
Middle age	2805	740
Old	2392	406

* Source Adapted from Ruch (1934)

exclude its operation as far as possible when ostensibly studying some other aspect is certainly undesirable It may be that the ability to acquire new behavior is not in itself changed with age but that a restriction on the speed of "intake" or 'out put places a limit on the kind or amount of learning which is possible The following are but a few of the possible examples of the sort of confusion referred to in this section

TABLE 3*

RECALL FROM INCIDENTAL LEARNING OF AN ALPHABETICAL CODE

	Average Age of Group		
	23 Years ($N = 28$)	29 Years ($N = 139$)	41 Years ($N = 104$)
No of items transcribed			
First period	59 8	56 0	47 3
Eighth period	87 8	83 9	70 1
Average gain	28 0	27 9	22 8
Probable error of average	1 2	0 7	0 7
Average no recalled	10 4	8 3	6 3
Probable error of average	0 7	0 3	0 3

* Source McGeoch and Irion (1952) p 532 from data of Thorndike *et al* (1928)

In one of Thorndike's (1928) studies on graduate students the subjects practiced an alphabetical code substitution, a sample of which is given below,

l z q
g k m

for eight 3 minute periods They were then asked to recall the code The number of items recalled in this incidental memory test are given with additional relevant information in Table 3

The difference between the average numbers of items recalled by the oldest and youngest subject groups is statistically reliable and considered to constitute evidence that learning ability was impaired in the older subjects This index also appears to be free of contamination by speed deficits, because there was no formal pacing on the recall test A glance at the numbers of items transcribed by these two groups during the practice sessions, however, reveals that the older subjects made about 20 per cent fewer substitutions If the number of items completed, rather than the amount of time spent in the situation, is regarded as the measure of training, it seems reasonable to assume that at least part of the difference between the average numbers of items recalled can be understood in terms of this difference in the amount of effective practice surreptitiously introduced by fixing the amount of time rather than the number of operations completed Moreover, the gain from the first to eighth practice session in the average number of items transcribed was taken as another measure of learning ability which showed the oldest subjects to be inferior learners It seems likely, however, that at least part of this disadvantage is also due to the speed deficit Since the older subjects work more slowly than the younger ones, it would, indeed, be surprising if they gained as much as the latter in absolute terms The oldest subjects did, however, increase their scores by 48 per cent, while the youngest showed only a 44 per cent gain It may well be that comparing the percentage gains in this fashion does more than simply compensate for the speed handicap, but it does seem less objectionable than permitting the speed deficit to pervade all evaluations of learning ability

A similar type of phenomenon was exhibited even more clearly in a digit symbol substitution test performed by Willoughby (1929) with similar incidental memory conditions Figure 3 shows both the recall scores and the average number of substitutions during practice as a function of age groups It will be noted immediately that the two types of score were related to age in very similar fashions If the number of correct substitutions is taken as a measure

of practice, it seems only reasonable to conclude with McGeoch and Irion (1952, p 531) that the data on recall may "demonstrate only that less practice yields smaller amounts of learning" while the data on the number of substitutions indicate a speed deficit that affects the amount of effective practice secured

These experiments exhibit rather crude intrusions on learning evaluations by deficits in speed of performance It can, however, operate in a much more subtle fashion through more or less conventionalized temporal scheduling Thus it will be noted that most standardized tests and routine laboratory experiments are typically administered with a rate of presentation that has been more or less intentionally adjusted to the "normal" work rate of subjects between the ages of 15 and 25 years It has moreover, often been chosen so as to be too fast for some small percentage of even these youthful subjects. It is to be anticipated therefore, in the light of the acknowledged speed deficit of the aged that the conventional presentation schedules of such tests and experiments may place the older person at a distinct disadvantage It seems worth noting moreover that in such cases there would be no explicit indication of the operation of this factor The effect of such "crowding" probably cannot be evaluated without the aid of a set of experiments explicitly designed to elucidate it. We need information on the optimum conditions of distribution of practice for different age groups.

III Acquisition

In the somewhat formalized studies of scientific investigations modification of overt behavior in some preselected direction is a necessary condition for the conclusion that learning has occurred It seems quite natural therefore that the impairment of the learning function allegedly associated with chronological aging should frequently be referred to as a decrease in the modifiability, or plasticity, of behavior (Thorndike, 1928 Anderson, 1956, Welford, 1958) Modifiability, in this sense, is usually evaluated by determining the frequency, relative or absolute, of the preselected behavior, usually called "correct response," at several times during practice When these frequencies increase with practice the subject is said to be acquiring the desired modification. When the rate of acquisition falls below some value accepted as normal, modifiability or plasticity of behavior is presumably depressed, and behavior is considered to become more rigid or intractable It is the purpose of the present section to review data relevant to an estimate of the extent to which such rigidity and intractability of behavior is associated with chronological aging

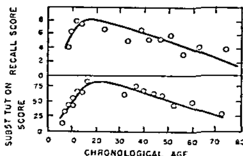


Fig 3 —Substitution and recall scores as a function of age from digit symbol code transcription practice followed by a test of incidental memory (After Willoughby 1929)

Human Subjects

USE OF INFORMATION

Thorndike (1928) referred to the following somewhat unusual psychophysical experiment as a study in "sheer modifiability" He compared two age groups (20-24 years, av 22 years, $n = 12$, 35 years or more, av 42 years, $n = 12$) with respect to their ability to draw, without visual cues, lines of specified lengths (3, 4, 5, and 6 inches) along a straight edge In the first session each of the subjects attempted to draw each of the lengths on command in a random order until six hundred lines had been produced. During the next seven ses

sions involving the same amount of work, the subject was given partial information concerning the accuracy of each attempt. An error of ⅛ inch for the 3 inch length and ¼ inch for all other lengths was allowed without classifying a response as incorrect. During the seven practice trials the subjects were informed of the correctness of their responses in this sense "A few days" after the last practice session, each subject had a second test run without information, consisting of six hundred trials. The results

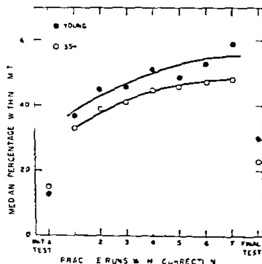


FIG 4.—Accuracy of drawing lines of various specified lengths for two age groups with and without information. (Adopted from Thorndike et al, 1928.)

are summarized in Figure 4, which shows the median number of "correct" responses for each of the age groups separately on the two tests and seven practice sessions.

Thorndike assigned the epithet "sheer modifiability" to this task because he felt that performance on it should be free, to a relatively great extent, from the influences of past experience The fact that the two groups of subjects performed so nearly alike on the initial test is at least consistent with his intuition. That there was a very great improvement in the older as well as in the younger subjects on the first trial with information and on subsequent trials indicates modifiability for both groups. It appears, however, that the older subjects were somewhat less modifiable, because they increased their relative frequency of correct responses only 18 per cent during the first practice trial, whereas the younger group improved by 24 per cent. Thus, although the two groups were about equally accurate on the initial test, the younger group gained more from the initial practice trial. Judging from the apparent parallelness of the functions drawn in Figure 4, however, the two groups, during the subsequent practice trials, improved about equally in their ability to use the information supplied during the sessions, but, owing to their initial gain, the younger subjects remained consistently superior When the information was withdrawn, for the final test, the relative frequency of correct response decreased approximately 23 and 25 per cent for the younger and older subjects, respectively.

These results suggest the operation of two types of modifiability one, a rather stable change in accuracy reflected by the difference between the initial and final tests, about 17 per cent for the younger and 8 per cent for the older subjects, the other, a more transitory but dynamic type of adjustment, is reflected by the marked decrement in accuracy associated with the withdrawal of information after the last practice trial. This latter form of adaptability suggests an almost continuous interaction between the subject's impression of his responses and the information associated with them from moment to moment. If the sort of plasticity required for this incessant adjustment to a highly fluid situation is adequately measured by the observed decrement in accuracy attendant upon the withdrawal of information, it appears that the two age groups were about equally endowed with it.

ESPERANTO

Thorndike (1928) has also performed a very interesting, controlled study of the learning of Esperanto which derives con

siderable appeal and face validity from its resemblance to conventional academic courses These materials were sufficiently novel to provide an opportunity for a good deal of improvement with practice and yet did not require a prohibitively long training period The experiment consisted of 10 hours of classroom instruction plus 10 hours of home study preceded and followed by examinations These tests consisted of four parts (1) a 100-item, multiple-choice vocabulary test, (2) a 27 item written directions test, (3) a 27 item oral directions test, and (4) a reading comprehension test with 19 questions Thirteen

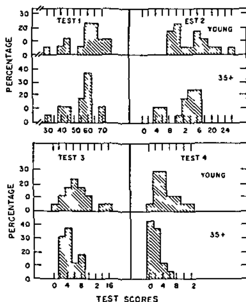


FIG 5—Distributions of scores on four initial tests in Esperanto for two age groups The numbers entered on the abscissa are the upper limits of the step intervals which are two score units for all except Test 1 for which the interval is five units (Adapted from Thorndike *et al* 1928)

minutes were allotted to each part, but, after this standard test period, additional time was allowed for the completion of items omitted due to time limits on the subtests The subjects were graduate students in education, 27 below 35 years of age and 21 above

Figure 5 shows the relative frequencies (percentages) of various scores on the initial subtests for the two age groups separately From these data it appears that the older subjects were markedly inferior to the younger ones on the oral directions and the reading tests (Tests 3 and 4) but, perhaps, equally good on the vocabulary and the written directions tests (Tests 1 and 2) It

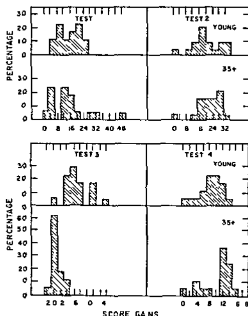


FIG 6—Distributions of gains on Esperanto tests for two age groups The numbers entered on the abscissa are the upper limits of the step intervals which include four score units in Tests 1 and 2 and two score units in Tests 3 and 4 (Adapted from Thorndike *et al*, 1928)

will be noted that performance on these tests required the recognition of similarities between English and Esperanto and the guessing of meanings on the basis of these recognitions There were, therefore, perceptual, associative, and integrative components in the task

In Figure 6 the relative frequency (percentage) of various amounts of gain from the first to the second test are shown for the two age groups separately on the several subtests These data indicate that on the vocabulary, written directions, and reading tests (Tests 1, 2, and 4) the older

subjects were able to profit at least as much as the younger ones from study and from the instruction given On the oral directions test, however, they were inferior This test, it should be noted, was designed to be equivalent to the written directions test The score discrepancies therefore, must be assigned to differences in the method of presentation and not to any fundamental differences in mastery of the subject matter The special difficulty may, of course, be temporal, since oral comprehension is undoubtedly influenced greatly by the rate of presentation

scholastic endeavor, and Groups II and III having had more recent relevant experience Miller's analogies test was administered at the beginning of the experiment, and the subjects kept a careful record of the amount of time they devoted to study for the test course

The results are reported in terms of various simple and partial correlation coefficients calculated separately for the three groups Some of these partial correlations are shown in Table 4 It will be noted that reliable negative correlations between age and achievement were obtained only in

TABLE 4*

PARTIAL CORRELATIONS BETWEEN AGE AND SEVERAL LEARNING RELATED FACTORS FOR THREE GROUPS OF SUMMER STUDENTS WITH INCREASING (I III) RECENCY OF PARTICIPATION IN ACADEMIC COURSE WORK

Correlated Factors	Factor Held Constant	Increasing Recency Group		
		I (N = 58)	II (N = 41)	III (N = 54)
Age—Achievement	Analogies	− 09	19	− 12
Age—Achievement	Study	− 19	11	− 03
Age—Study	Analogies	45	43	02
Achievement—Analogies	Study	57	42	48
Achievement—Study	Analogies	39	30	− 12
Age—Achievement	Analogies, Study	− 32	09	− 12

* Source Sorensen (1930)

ACADEMIC ACHIEVEMENT

The very frequently encountered notion that lack of practice is the explanation for increasing disability with advancing age derives considerable support from the work of Sorensen (1930) In this study, 153 elementary school teachers (36 above the age of 40 age range 20–56 years, mean age 35 years) served as subjects, and their achievement in a course giving credit toward a Bachelor's degree in education was used as an index of learning ability Three groups of subjects were differentiated on the basis of the continuity and recency of their experience with the academic routine of acquisition, Group I being characterized by a presumably lengthy interruption of Group I, whose members lacked recent exercise in the academic procedures of acquisition Among the subjects, Group II and Group III, who had recently exercised their acquisitive powers, there was no evidence of deterioration. This result is interpreted as supporting Thorndike's opinion that much of the apparent loss in the ability to learn attributed to aging individuals can be understood in terms of disuse or lack of practice

A SERIAL LEARNING TASK

Kay (1951) presented two serial learning problems to ten subjects in each of the age decades from the twenties through the sixties His apparatus consisted of a row of

ten lights in front of the subject and a row of ten telegraph keys each in front of a light The lights and keys were labeled by a common set of numbers placed between them Control circuits were arranged so that, with any given light on, one and only one key would turn it off and turn on some other light, a different key operating each light The subject's task was, in general, to cause a series of five lights to go off by an appropriate selection of keys in a predetermined order, that is, he was required to learn this order The first problem was confined to the first five keys from the left and the correct order of selection was 2, 4, 3, 1, and 5 In the second problem the remaining set of five keys was used and the predetermined order of selection was 7, 6, 10, 8, and 9 Between each trial or series of five correct operations there was a 15 second pause When the subject had learned the first task to a criterion of two complete trials without error, he worked on the second problem until he mastered it to the

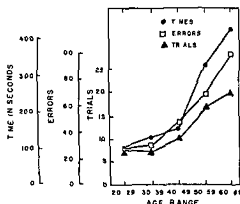


Fig 7—Mean times, errors and trials required by various age groups to achieve the criterion of two consecutive trials without error (From Kay 1951)

same criterion He then relearned the first problem to one correct trial and then relearned the second to this latter criterion

The data were reported in terms of three indexes total time required to achieve the criterion, number of trials required, and total number of errors committed The data from the two problems were combined by Kay (1951) and are shown in Figure 7 for the original learning It will be observed that, in order to reach the criterion, the oldest age group required, on the average, twice as many trials, made more than twice as many errors, and used more than four times as much time as the youngest age group did The corresponding within age

TABLE 5*

WITHIN AGE-GROUP STANDARD DEVIATIONS OF TRIALS, TIME, AND ERRORS REQUIRED TO *MEET CRITERION OF TWO ERRORLESS TRIALS* ON A KEY LIGHT PERFORMANCE TEST†

Age Group	Trials	Time	Errors
20–29	2 38	22 62	15 33
30 39	4 31	41 95	18 40
40–49	5 11	34 59	21 82
50–59	6 85	92 07	44 43
60–69	11 30	155 30	69 91

* Source Kay (1951)

† The indexes refer to combinations of individual performances on two tasks

group standard deviations are shown in Table 5 The variances on which they are based, unfortunately, include between test variability It is clear that the members of the older generations differed more from one another than did the members of the younger generations It was pointed out, however, that these standard deviations are roughly proportional to their corresponding means so that the relative variability is approximately constant The increasing between individual variability with age is a recurrent phenomenon that *will be discussed in a later section*

From an analysis of the errors that occurred Kay (1951) developed an interesting notion concerning the sort of psychological processes that constitute learning in this situation These errors were of two classes, "spatial expectancies" and "anticipatory errors" The former class may be exemplified by an apparent preference for right to left movements over left to right movements, at least "we find the errors scored were 946 from left to-right and 1,506 from right to left" This class of er-

tor also included a tendency to alternate the direction of movement, that is, there was a marked propensity for movements to the right to be followed by movements to the left and vice versa In general these spatial expectancies seemed to be action tendencies which the subjects brought to the experiment rather than habits devel

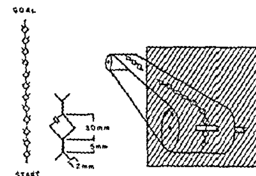


FIG 8 — Moving maze A sheet of paper bearing the printed maze and being driven past the exposure field by a drum arrangement is schematically represented on the right The dimensions of a maze unit are shown in the middle diagram and the complete pattern is represented on the extreme left (After Wright 1957)

oped in it The anticipatory tendencies which consisted in striking a key which though an error on the particular choice in question would subsequently be correct within the trial most frequently the key that would be correct on the next choice presuppose some degree of familiarity with the series and did in fact require some time to develop

From these error analyses, Kay (1951) came to the conclusion that 'for many subjects, therefore learning was a process involving much unlearning and much amendment As ever, the poorer performer was executing the harder task. He was spending much of his time trying to unlearn an error which he had himself brought into the task, and he still had to learn the correct response' (p 183) With respect to age differences in this connection, he says 'It should be stressed that errors and error repititions were not differently distributed between age groups, but the older subjects were exaggerating the repetitive tendencies which were typical of all age groups" (p. 177)

The data on relearning are not included because the design of the experiment in this connection makes them difficult to interpret. They cannot be regarded as transfer data since no control group without intervening work was run, and they cannot be regarded as retention data because intervening, and possibly interfering work was given

PAPER MAZE

Wright (1957) has compared two age groups (18–25 years and 46–55 years, median 50 years) with respect to their ability to learn a twelve choice point maze printed on a long strip of paper driven by a drum in the apparatus illustrated in Figure 8 The subject's task was to follow the true path with a stylus through an aperture that exposed only a small part of a maze unit at a given moment The maze was driven past the aperture at a rate that allowed 2 8 seconds per unit The criterion of learning was two successive trials without error, and the results are shown in Table 6 in terms of the number of trials required to reach the criterion the average number of errors per subject, and the average amount of time required.

TABLE 6*

TRIAL, ERROR AND TIME INDEXES FOR LEARNING A TWELVE-CHOICE-POINT PAPER MAZE TO A CRITERION OF TWO ERRORLESS TRIALS

	Young		Old	
	Mean	S D	Mean	S D
Trials	19 33	9 53	28 25	8 58
Errors	72 92	42 65	95 50	30 45
Time	865 4	431 3	1269 2	385 0

* Source Adapted from Wright (1957) pp. 65 and 120

The superiority of the younger subjects with respect to time and trials was statistically reliable, but the difference in the number of errors committed by the two

groups was not The younger subjects made more errors per trial than the older ones did, but they required many fewer trials There is little doubt that the older subjects performed less efficiently on this task than the younger ones It may be noted, however, that the pacing speed was selected for the convenience of the latter and may, therefore, have been less likely to elicit optimal performance from the older subjects This apparatus and problem seem well designed for studying the influence of pacing on age differences in learning ability Indeed, pacing was one of the principal variables investigated in the main body of the study on young subjects

lus cards, each being placed on one of the sorting slots In all problems there was an additional sorting area designated "bin" into which all cards that could not be matched to stimulus slots according to instruction were to be placed Thus, under the instructions and conditions being considered, all 1's, 2's, 4's, 7's, 8's, and 10's, regardless of suit, were to be placed in the "bin," and all 3 s, 5's, 6's, and 9's were to be sorted into slots bearing stimulus cards with corresponding numbers, again regardless of suit

In each problem the pack was sorted four times by each subject to provide an opportunity for learning Problems of vari-

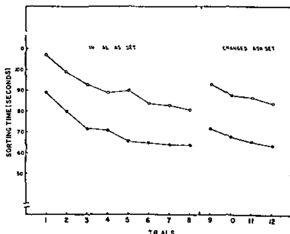


Fig 9—Average times on successive trials for two age groups in card sorting on two different arrangements of the same stimulus cards (After Botwinick *et al* 1959)

CARD SORTING

Botwinick *et al* (1959) have studied card sorting performance in relation to age (27 males 65–81 years, median age 71 0, 30 males 19–35 years, median age 24 5) for various degrees of difficulty and "complexity" The basic task consisted in sorting 71 playing cards (face cards omitted) under several matching instructions into various numbers of slots bearing stimulus cards For example, consider a four slot problem with speed instructions to match for number In this problem the nine of hearts, the six of spades, the five of hearts, and the three of clubs were used as stimu-

ous difficulties were constructed by varying the number of slots (2, 4, 6, 8, and 10) into which cards were to be sorted, and problems of various "complexities" were obtained by changing the matching instructions The lowest degree of complexity was represented by the number-matching instruction illustrated above The next level required a number matching only if color (black or red) matched, and the greatest degree of difficulty required the subject to match "cards by number and color if the number is even, but if the number is odd match numbers and opposite color"

The data for Figure 9 were obtained

from a six slot experiment, with number-matching instructions, in which the stimulus card arrangement was changed after the eighth sorting and four additional trials were given with the new arrangement The results are expressed in terms of the mean sorting times on successive trials The problem of initial level is very clearly illustrated in this figure It will be noted that *the two age groups differed markedly in* their sorting times on the first and all subsequent trials but the rate of decrease in sorting time (the index of learning) was very nearly the same in the two groups Although the groups appear to be differently affected by the change in arrangement (eighth to ninth trial) the difference was not statistically reliable

These data and others from this experiment suggest that although the two age groups differed markedly with respect to their ability to perform the task in question, it is difficult to detect any difference in their ability to profit by experience We cannot, however, completely ignore the fact that the younger subjects began their learning very much closer to some general physiological limit than did the older subjects *It would seem to be of special inter-*est in this connection to attempt to discover to what extent the physiological limits for young and old subjects differ on tasks of this nature, especially for various difficulties and "complexities"

CONDITIONED EYEBLINK

Gakkel and Zinina (1953) have investigated, in a home for invalids, the effects of age on the acquisition and differentiation of the conditioned eyeblink reflex Passing a stream of air three times over the cornea was employed as the unconditioned stimulus, the sound of a buzzer as the stimulus to be conditioned, and the sound of a bell as the stimulus to be differentiated The indexes of conditioning were vascular, respiratory, and impellent blink responses, of which only the last gave satisfactory results A test session lasted about 15 minutes

The subjects were also given a word association test consisting of twenty five standard word stimuli to which they were instructed to respond with a single word. By way of an external inhibitor, a bell of average intensity was sounded The results of this investigation, together with those from the conditioning tests, are given in Table 7 for individual subjects

Because no control group was run for comparison purposes, the performances of these aged invalids must be evaluated in terms of some unspecified data from younger subjects It is stated in this connection that the average latency of response is 1 2 seconds for normal subjects on the word association test In general, it was concluded that the process of conditioning was markedly prolonged in these aged invalids. Failure to obtain even the gross differentiation between the sounds of the buzzer and the bell was accepted as indicative of a serious impairment of the process of inhibition, and a high frequency of garrulous re-*sponses in the word association* test was regarded as supporting this conclusion

In a recent study of eyeblink conditioning Braun and Geiselhart (1959) have avoided both of the principal *ambiguities* of Gakkel and Zinina's (1953) design by securing comparison data from two groups of young subjects (15 males, 8–10 years mean age 9 36, 15 males, 18–25 years, mean age 20 63) as well as from aged subjects (13 males, 62–84 years, mean age 70 5) who were living in the community as presumably healthy individuals

An adaptation of Spence's apparatus was employed, the subject and the control devices being in separate rooms The stimulus to be conditioned was an illumination increment (0 05–1 5 foot candles, duration 1 second) on a small stimulus patch in front of the subject. The unconditioned stimulus was a puff of air (2 0 pounds per square inch, duration 500 milliseconds), and the CS-UCS interval was 500 milliseconds Intertrial intervals of 10, 15, and 20 seconds were employed in a prearranged order Each subject was given 80 conditioning

trials followed by 20 extinction trials The air puff was delivered during extinction, but the CS UCS interval was lengthened to 1500 milliseconds

Figure 10 shows, for successive blocks of ten trials and for the age groups separately, the percentage of trials on which conditioned responses were obtained during both the conditioning and the extinction tests The aged subjects differed significantly from both the children and the young adults with respect to the total number of conditioned responses given during the conditioning run and the young adults were not significantly different from the children in this connection The age differences in extinction, tested by covariance analysis, were also unreliable

"The main and striking finding of this study is the relative inability of the elderly *S* s to acquire the conditioned eyeblink response" To explain this "relative unconditionability" of the older subjects, the authors offer an intriguing "adaptation hypothesis" according to which "it is proposed that in the course of many years of living, the eyeblink response as well as probably other responses have been 'adapted out' and thus less susceptible to subsequent conditioning"

TABLE 7*

RESULTS OF EYEBLINK CONDITIONING DIFFERENTIATION AND A WORD ASSOCIATION TEST ON FOURTEEN AGED PATIENTS

Age	Composite Method			Associative Experiment		
	Fixation Rate of Conditioned Reflex (by No of Associations)	Latent Period (in Seconds)	Differentiation Formation Rate (by No of Non intensified Stimuli)	No of One Word Responses	Latent Period (in Seconds)	No of Repeated Answers
65	6	0 4	10	24	1 7	3
69	20	1 2	No (differentiation) developed			
73	23	1 2	3			
75	35	1 2	No (differentiation) developed	12	2 3	18
75				8	3 1	10
75				15	2 4	20
77	34	1 2	24 (incomplete)	19	2 4	10
77	50	1 5	No (differentiation) developed	3	2 4	25
79	90	1 5	No (differentiation) developed			
85	40	1 0	26 (incomplete)			
85	24	1 0	30	9	2 3	10
85				4	2 0	25
90	90	1 1	50 (incomplete)			
90				12	2 5	12

* Source Gakkal and Zinina (1953)

CONDITIONED HAND WITHDRAWAL

Marinesco and Kreindler (1934) have studied several of the phenomena of conditioning in aged subjects with their adaptation of Bechterew's association method The subject was seated in a dimly illumi

nated room with his hand on a mobile plate, the movements of which were re corded on a kymograph located outside of the room The unconditioned stimulus was a faradic current that passed through the mobile plate and caused a reflex retraction of the subject's hand, the movement of which was recorded The stimuli to be con ditioned were the ringing of a bell or a colored light The results are not reported in a quantitative fashion but are introduced in support of conclusions and interpreta tions in the following fashion

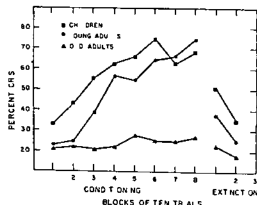


FIG 10 —Relative frequencies of conditioned eye-blink responses on successive blocks of trials for three age groups during conditioning and extinction procedures (After Braun and Geiselhart 1959)

1 The acquisition of a conditioned motor reflex is achieved more slowly by aged men than by younger adults The authors find that the responses in question can be established in 30–40 trials in younger adults but require 80–90 trials with aged subjects

2 Irradiation and concentration are achieved with relative difficulty by the aged subject This follows from the fact that the retraction response of the older subject was not so diffusely generalized as the younger subjects' response during the early stages of conditioning or so finely differentiated during the later stages

Internal inhibition in its many forms is modified in the following manner among the aged

3 Differentiation is only slowly established in the aged Among young adults differentiation between a red and a yellow light is usually established by 15 or 20 presentations of the unreinforced stimulus but the aged subject usually requires 50–75 such presentations Two subjects, aged 83 and 90, failed to make the differentia tion within 120 trials

4 Extinction is achieved slowly by the aged subject Young adults usually extin guished in this situation after 8–10 extinc tion trials Among aged people 20–25 trials were required One woman, aged 75, re quired 70 trials

5 Trace conditioned reflexes are diffi cult to obtain among old subjects Man nesco and Kreindler (1934) were unable to establish this type of response in any of their eight subjects between the ages of 75 and 90 years, but found it easy to establish them in children

The authors' conclusions from these observations are somewhat paraphrased for the purpose of condensation in the follow ing statements These findings in connec tion with the conditioned reflex enable us to understand certain facts of the psychology of old people Being slower to establish conditioned reflexes, they manifest a cer tain refractoriness toward new acquisitions Aged persons are distracted because excita tion cannot attain a maximum degree at any point on the cortex but is irradiated over a rather large surface, owing to this latter fact, other points can also find them selves in a state of excitation and thus pre vent maximum concentration Owing to malfunctioning in the process of differen tiation, factual criticism is deficient Adap tation to new external conditions is also poor, on the one hand, because the aged person acquires new conditioned reflexes with difficulty and, on the other hand be cause established conditioned reflexes are easily established These latter are, in fact the basis of the syllogism Judgment which is a succession of logical phrases, is born of

the fact that the preceding phrase becomes the conditioned stimulus for the phrase that follows it in the series of conditioned reflexes of very high order that is language (Marinesco and Kreindler 1934, pp 730–31)

Even if these somewhat expansive interpretations are not accepted without reservation, those data that are presented suggest a higher degree of plasticity and modifiability of behavior in younger subjects than in older ones It is unfortunate, of course, that the quantitative results were not reported in greater detail and that the physical status and intellectual level of the subjects were not described more fully

Animal Studies

In spite of the deterrents to such work there are several important investigations of the effects of aging on the ability to learn in lower organisms available for comparison with the results obtained from human subjects They comprise a rather considerable amount of work on the albino rat in a variety of mazes and problem boxes which is outlined in highly condensed form in Table 8 Clearly only a few of these studies can be reviewed within the space appropriate to this section

The first column in Table 8 exhibits the variety of tasks employed to seek out the effect in question It also gives page references and indicates a number of experiments omitted from the table because they did not employ near senescent animals The second column shows the number of animals, in parentheses, in each of the age groups represented together with Stone's (1929*a*, 1929*b*) description of the stage of life corresponding to these ages The weight effects of the deprivation schedules employed are shown in the third column Finally, the author's evaluations of the outcome of the various experiments are given in the last column It should be remarked that these evaluations are not always those that are most directly suggested by the data

There are then thirteen directly relevant studies supplied by three investigators three escape problems, in two of which the younger animals were superior on time scores, six maze studies, five of which showed no impairment of this nature, three studies on a light-discrimination problem which showed no consistent age differences, and a counter training study on the latter problem in which a deficit for the older animals did occur

MAZE PROBLEMS

Using a Watson circular maze with a camera lucida, Hubbert (1915) compared the learning abilities of several age groups of rats All animals were gradually brought to the same level of deprivation according to which they were allowed access to bread and milk for 5 minutes a day Two training trials were given every day, and each animal worked until it had eliminated all "useless movements" for 3 days The results are summarized in Table 9, which shows the number of trials and the total time required to reach the criterion The average speed, obtained from tracings of the paths traversed by the animals, is included merely to illustrate the general finding that speed of operation decreased markedly with age

It will be noted that, although age groups older than 65 days required more trials than younger groups, they did not differ among themselves The oldest animals would probably be described as in late mid life by Stone (1929*a*, 1929*b*), and the 65 day old rat is about at the age of puberty Thus Hubbert's results showed no significant change in learning ability between early maturity and late mid life

With a thirteen choice point, multiple T maze, schematically represented in Figure 11, Stone (1929*a*) compared the learning abilities of four age groups of rats covering the range from pre-pubescence to senescence The animals were run once a day under what was considered strong motivation induced by differential deprivation for age

TABLE 8

SUMMARY OF EXPERIMENTS RELEVANT TO OLD AGE AND LEARNING ABILITY IN RATS

Type of Problem	Age of Groups in Days (N)	Deprivation	Results
Problem box			
Lever escape Stone (1929a pp 11–25)	30 (80) mid infancy 50 (96) mid puberty	Gained 1.75 gm/day Gained 1.25 gm/day	30- and 50-day old rats escaped more quickly—young rats more active and impulsive
Learning and relearning	100 (98) postpubertal 240 (38) middle aged 730 (28)		Relearning after 70 days showed no relation to age
Three plate escape (Stone, 1929a pp 26–49)	125 (25) early adulthood	Gained 1.5 gm/day	Younger group superior on time
(Two experiments on young groups omitted)	400 (35) well along in middle age	Maintained	
Learning and relearning	350 (25) prime of life 555 (25) early senescence	Maintained Maintained	No difference
Mazes			
Watson circular Maze Hubbert (1915) No relearning	25 (27) 65 (27) 200 (28) 300 (28) 500 (12)	Fed 5 min per day on bread and milk for all age groups	Adult and old animals not reliably different, pubescent and prepubescent superior to adult animals
Modified Carr (Stone 1929a pp 50–82) Learning and relearning	30 (28) 30 (23) 50 (40) 70 (42) 120 (42) 260 (20) 750 (28)	Maintained Gained 2 gm/day Gained 1.8 gm/day Gained 1.5 gm/day Maintained Lost 0.8 gm/day Lost slightly	Older rats retraced less—rats older than 70 days learned better than younger rats
Multiple-T Stone (1929a pp 83–126)	35 (47) Very young	Gained 1.6 gm/day	No unequivocal evidence of an age difference
Three experiments with young groups omitted (relearning performed only with younger groups)	70 (54) 470 (17) fully developed adult 745 (6) Old	Gained 0.8 gm/day Slightly below maintenance Lost 1.0 gm/day	
Stone (1929b, pp 98–107)	100 (46) postpubertal 180 (45) adult 300 (50) early mid life 380 (60) mid life 525 (25) late mid life	Gained 0.6 gm/day Maintained Lost 0.3 gm/day Lost 0.3 gm/day Lost 0.3 gm/day	No age differences observed
Very difficult maze			
Stone (1929b pp 176–94)	51 (21) 160 (19) 221 (23) 566 (19)	Gained 0.6 gm/day Lost 0.5 gm/day Lost 0.5 gm/day Lost 0.2 gm/day	Reliable superiority of youngest group in both time and errors—remaining groups quite similar to one another—no age decrement among adults The oldest group had experience on the multiple-T maze prior to being used in this experiment

TABLE 8—*Continued*

Type of Problem	Age of Groups in Days (*N*)	Deprivation	Results
Very difficult maze—Continued			
Verzar McDougall (1957) multiple T learning and *relearning*	2 to 3 mo (40) 8 to 9 mo (43) *12 to 18 mo (20)* 20 to 27 mo (42) 30 mo (12)	Deprived so as to cause 20 per cent *weight loss during* 30 days experiment, exception in younger group necessary, small group not deprived	From adult to old age an increasing relative frequency *of failure to* learn within 26 trials
Discrimination			
Problem Stone (1929*b*, pp 131–67)	40 (21) prepubescent	Gained 0 7 gm/day	Results very similar for all groups
	150 (19) postpubescent	Gained 0 2 gm/day	
(Three experiments on younger animals omitted)	20 (23) younger adult	Gained 0 7 gm/day	
	236 (19)	Lost 1 4 gm/day	
Problem Stone (1929*b*, pp 131–67)	40 (21) prepubescent	Gained 0 7 gm/day	Results very similar for all groups
	150 (19) postpubescent	Gained 0 2 gm/day	
	210 (23) younger adult	Gained 0 7 gm/day	
	236 (19) young adult	Lost 1 4 gm/day	
(Three experiments on younger animals omitted)	760 (7) senescent	Lost 1 4 gm/day	
	40 (31)	Gained 1 5 gm/day	266-day group slightly inferior on error scores—all other groups very similar
	115 (15)	Maintained	
	266 (20)	Maintained	
	451 (20)	Lost 0 5 gm/day	
	340 (24) early mid life	Maintained	No observable difference
	550 (18) end of mid life	*Lost 0 3 gm/day*	
Counter training in discrimination problem	80 (21)	Not given	Various age groups broke up old habit at about same rate but older animals acquired new habit more slowly
Stone (1929*b*, pp 167–72)	276 (19) 780 (7)		

The data are reported in several ways (1) median number of trials required to reach the two following criteria (*a*) not more than three errors in three consecutive trials and (*b*) not more than one error in three consecutive trials, (2) average time per trial at various times during the training, (3) average number of errors per trial as a function of trial number, and (4) average number of errors in the first as compared with the second fifteen trials In Table 10 the median numbers of trials required to meet the two criteria by the several age groups indicate a reliable superior

TABLE 9*

AVERAGE NUMBER OF TRIALS AND AMOUNT OF TIME REQUIRED TO MEET A CRITERION OF SIX ERRORLESS RUNS AND AVERAGE SPEED SCORE FOR SEVERAL AGE GROUPS OF RATS

Average Age (in Days)	*N*	Trials	Time (Minutes)	Speed (Cm/Sec)
25	27	30	224	20 1
65	27	31	219	19 8
200	28	42	351	16 0
300	28	41	743	8 2
500	12	38	557	9 9

* Source Hubbert (1915)

ity for the two younger groups but show no advantage for the middle age group over the senescent one In Figure 12, which shows the average number of errors on successive trials essentially the same relation is seen to obtain From the fourth to the fourteenth trial, the two younger groups consistently had the advantage over the older groups, but the latter did not differ from one another This result agrees well with Hubbert s and from it Stone concluded ' Young middle aged and relatively old animals learn the multiple T maze at nearly the same rate when strongly motivated No evidence of a measurable gain in learning ability through the pre and post adolescent period was found' (1929a, p 96)

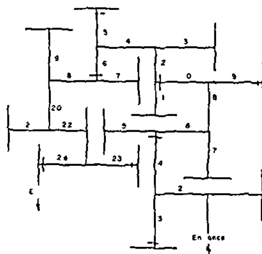


FIG 11 —Ground plan of Stone s multiple T maze The doors were employed to prevent retracing the pseudo doors to give the alleys similar appearance at both ends (After Stone 1929a)

TABLE 10*

MEDIAN NUMBER OF TRIALS REQUIRED TO ACHIEVE TWO CRITERIA OF LEARNING ON A THIRTEEN CHOICE POINT MULTIPLE T MAZE

	Age Group (in Days)			
	31 60 (N=47)	56 85 (N=54)	456 85 (N=17)	730 59 (N=6)
Not more than 1 error in 3 trials	20 4	15 5	22 0	19 0
Probable error of median	0 6	1 0	1 21	
Not more than 3 errors in 3 trials	13 9	12 7	17 0	16 0
Probable error of median	0 17	0 17	0 91	

* Source S one (1929a)

In an experiment very similar to Stone s insofar as the acquisition trials were concerned Verzar McDougall (1957) compared several age groups of rats under a

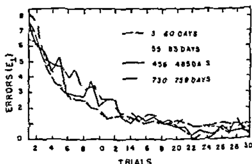


FIG 12 —Average number of forward entrance errors on successive trials by several age groups in a mult ple T maze (After Stone 1929a)

deprivation schedule that was not differentiated according to age During a pretraining period the animals were gradually adapted to the feeding routine and to the maze situation by preliminary work in a straightway The deprivation schedule was originally selected to cause a 20 per cent weight loss in all groups over the 30 days of experimentation Evidently, this plan encountered difficulties, however, for, as regards the degree of motivation it must be noted that group B [2 month old males] was very severely restricted in food so that the rats lost weight for the first 10 days of the trials' (p 70) These animals had to be given supplemental rations Moreover it seems worth noting that the members of Group F w°re deliberately less severely

motivated, they learnt the maze better than the 2 female groups without being restricted in food and having only a reward of dry maise corn as motivation" (pp 70–71)

Under such deprivation schedules, the animals had one trial a day on the maze for 26–30 days, or until they learned it to the criterion of "not more than 3 total errors in 3 consecutive runs' A time criterion of "not more than 60 total seconds in 3 consecutive trials" (p 67) was added The results of these tests are shown in Figure 13 for the several subgroups employed The ordinal values give the number of trials required to meet the error criterion, and each dot represents an individual performance Animals that did not satisfy the criterion are represented in the upper margin of the figure marked "> 26 ' Table 11 provides a convenient summary of these results It will be noted that the relative frequency of failure increased markedly from the ninth to the thirtieth month There is in these data, then, a strong suggestion of age differences in learning ability among adult rats, but Verzar McDougall calls at

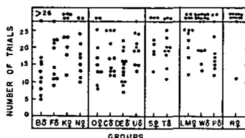


FIG 13 —Number of trials required by several age groups of rats to reach a criterion of not more than three total error in three consecutive runs in a multiple-T maze Each point represents an individual score Points entered in upper margin represent animals that failed to meet the criterion within twenty six trials (After Verzar McDougall 1957)

Age category 1 2 3 months old 40 rats
Group B 10 male rats 2 months old
F 10 male rats, 2 months old
K 10 female rats 2 months old
N 10 female rats, 3 months old

Age category 2 8–9 months old 43 rats
Group O 10 female rats 8 months old
C 10 male rats 9 months old
DE 13 male rats 9 months old
U 10 male rats 9½ months old

Age category 3 12 18 months old 20 rats
Group S 8 female rats 12 months old
T 12 male rats, 18 months old

Age category 4 20–27 months old 42 rats
Group LM 13 female rats 20 months old
W 17 male rats, 22 months old
P 12 male rats, 24–27 months old

Age category 5 30 months old 12 rats
Group R 12 female rats 30 months old

TABLE 11*

ANALYSIS OF THE INITIAL LEARNING OF A MULTIPLE-T MAZE BY SEVERAL AGE GROUPS OF RATS

Age Category	No of Rats	Sex	Per Cent That Did Not Learn within 26 Trials	Average No of Trials To Learn of Others	Per Cent That Did Not Reach Time Criterion in 26 Trials	Average No of Trials To Reach Time Criterion
2 3 months (Groups B F K and N)	40	20M 20F	15 0	16 5	30	13 9
8–9 months (Groups O C DE, and U)	43	33M 10F	4 7	16 5	0	16 6
12 18 months (Groups S and T)	20	12M 8F	30	18 8	40	17 5
20–27 months (Groups LM, W, and P)	43	30M 13F	44 4	19 5	60	17 9
30 months (Group R)	12	F	83 3	18 5	83 3	20 0

* Source Verzar McDougall (1957)

tention to the fact that, "while it can be seen from Fig 1 [our Fig 13] that the 2 old categories of rats aged from 12 to 27 months show as a group less learning of the maze, there are nevertheless 55 to 70% re spectively in the 2 categories which did learn the maze within 26 trials—while the rats from 12 to 27 months learn less well *as a group*, about half of them learn equal ly well as the rats of 8–9 months" (p 72)

DISCRIMINATION PROBLEM

Presumably in order to increase the va riety of situations in which age differences in learning ability have been sought, Stone (1929*b* pp 131–75) performed six experi ments in the discrimination box schemati cally represented in Figure 14 Under typi cal operation conditions the animal was introduced into the discrimination cham ber through door Do_1, which was then lowered In each test unit one or the other of two frosted glass windows, *W*, was illu minated by transmitted light, and the ani mal was required to choose the alley on the illuminated side If it entered the other alley, it found itself blocked by a gate, G_1 or G_2 When the rat entered the next sec tion, Do_2 was lowered to prevent retracing, and the procedure described thus far was repeated until the subject completed the trial by passing through the exit door The position of the illuminated window was shifted from side to side within each unit from trial to trial according to a prear ranged schedule Several age groups of ani mals were tested in this situation under high motivation induced by differential deprivation of the type routinely employed by Stone Three consecutive runs (fifteen choices) without error were employed as a criterion of mastery Table 12 shows the median number of trials required by the members of various age groups in order to meet this criterion

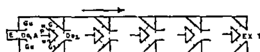


Fig 14 —Ground plan of Stone s discrimination box The animal was placed in *E* and door Do_1 was raised to give entrance into the first discrimination section to begin a trial *Gu* were small side panels used to direct the animals movements toward the discrimination panel containing the two windows *W*, only one of which was illuminated on a given trial *P* was a partition separating the two windows G_1 and G_2 were gates used to block one of the pas sages in each section The subject s task was always to use the passage on the side of the illuminated window Do_2 was the entrance to the second unit (After Stone 1929*b*)

It will be observed that the differences between age groups in this connection were small and unreliable Figure 15 shows the average number of errors in successive groups of five trials for the several age groups separately Again, it will be noted, the differences associated with age were slight and unsystematic Stone (1929*b*, p 146) concludes "Close similarity of all data from the five groups is the outstand ing feature of this experiment in which ani

TABLE 12*

MEDIAN NUMBERS OF TRIALS REQUIRED BY SEVERAL AGE GROUPS OF RATS TO LEARN A LIGHT DISCRIMINATION PROBLEM TO THE CRITERION OF FIFTEEN CONSECUTIVE CHOICES WITHOUT ERROR

	Age of Group (in Days)				
	31 50 (N=21)	141–60 (N=19)	201 20 (N=23)	226 45 (N=19)	751 70 (N=7)
Median	19 3	17 5	19 5	19 0	21 0
Probable error of me dian	3 73	3 65	2 53	2 80	

* Source Stone (1929*b*)

mals with great age differences and even differences in previous training were trained under optimum conditions of motivation"

Discussion of Acquisition Materials

The results from a large number of investigations, employing among them a great variety of test materials, suggest that it is possible to find, in the aged human subject, indications of an impairment in the ability to learn certain materials in certain ways It does not, as yet, seem feasible to attempt a detailed characterization of these materials and methods of study but it does seem highly likely that tasks which require the subject to learn under time pressure, or which evaluate his performance in terms of speed, are well chosen to reveal impairment of the ability to learn in the aged individual

It also appears important, however to discover if there are any other properties of the procedure or materials which facilitate the detection of age deficits, for, if there are no effects of age upon learning except those which are directly traceable to the well established speed deficit, it is desirable to be aware of this fact That this is not the case seems to be suggested by Kay s (1951) experiment, in which the subjects, though urged in the instructions to work as fast as possible, were not otherwise pressed for speed or paced in any clearly important manner A deliberate search for the essential properties of age-sensitive tasks, like this one, seems highly desirable

With infrahuman subjects, on the other hand, it appears to be difficult to demonstrate convincingly an age related learning deficit. It may well be that this difficulty arises, in part at least from the comparative psychologist's tendency to avoid confounding speed and learning indexes He usually expresses amount of practice in work units rather than in terms of time and treats speed measures as supplemental rather than essential For whatever reason, however, numerous studies are in agreement with respect to finding no evidence to the effect that aged animals learn less readily than fully mature, but not superannuated, specimens The lone dissenter in this connection is Verzar McDougall (1957), who chose not to deprive differentially the various age groups As a result, the observed deficit in ability to learn associated with age in this experiment could have been anticipated on the basis of the probability that the age groups were differentially motivated in the direction of the indicated learning differences

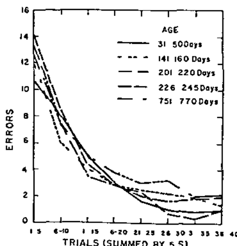


FIG 15 —Average number of errors in successive groups of five trials in Stone s discrimination learning problem (After Stone 1929*b*)

The resolution of this dilemma of motivation apparently can be achieved in two ways by finding some procedure capable of inducing equal degrees of motivation in various age groups when hunger is used as the drive or by discovering some source of motivation that does not appear to affect the various age groups differentially Some beginning has been made on this latter problem (Botwinick *et al*, 1957), but additional work remains to be done in this direction

Finally, it seems worth noting that, in spite of the fact that such an investigation with rats would not necessarily require more than 2 years, there has been, as yet,

no effort to design longitudinal studies of the effects of age on the ability to learn in lower animals There is no doubt that the design of such an experiment would place great demands on the ingenuity of the investigator In this connection particular consideration may be given Verzar Mc Dougall s longitudinal study of retention which is summarized in the following section

TABLE 13*

RELATIVE FREQUENCY OF VARIOUS EVALUATIONS OF THE INTELLECTUAL CAPACITIES AND OF THE MEMORY OF AGED PATIENTS BY THEIR PHYSICIANS

EVALUATION	AGE GROUP		
	80 90	90 100	100 and Over
Intellect			
Number interviewed	*588*	*184*	*46*
High	15	16	24
Moderate	75	72	63
Low	10	12	13
Memory (recent)			
Number interviewed	*481*	*153*	*39*
High	59	58	67
Moderate	24	20	18
Low	17	22	15
Memory (past)			
Number interviewed	*565*	*175*	
High	78	79	
Moderate	13	16	
Low	09	12	

* Source Humphrey (1889)

IV RETENTION

When anything is said to be *remembered* the implication is that it has been *learned* and that it has been *retained* during an *interval in which* it was not actively remembered Learning retaining remembering are three successive stages in the whole memory function In learning work is done by the organism this work leaves after effects which we may include under the noncommittal term *trace* What is retained is this trace The trace is a modification of the organism which is not directly observed but is inferred from the facts of recall and recognition [Woodworth 1938 pp 5–6]

The retention aspect of the total memory function is the primary concern of this section, and this quotation was selected to stress the fact that retention is tested by recalling, recognizing, or relearning with savings materials that have been *learned* If there is any question as to whether a given item has been learned, failure to recall, recognize, or relearn it does not constitute evidence that it has been forgotten it may never have been acquired Recall, recognition, and relearning are usable as measures of retention only when they can be referred to comparable measures of acquisition Some of the materials reviewed in this section are subject to the ambiguities that arise when this point is disregarded

Human Subjects

OPINION SURVEY

The belief that aging brings with it a loss of memory is, of course, an extremely popular conception (Richardson, 1933, Gilbert, 1941) commonly accepted by both the young and the old Humphrey (1889) made a rather frontal assault on this notion through an opinion survey in which a nine hundred patients who had reached or exceeded their eightieth birthday Table 13, adapted from several of Humphrey s tables, shows the relative frequency with which individuals in various age categories were judged to have high, moderate, or low intellectual abilities and memory powers.

It is, of course impossible to know precisely what the various physicians intended by their use of the categories of judgment employed, but these data do indicate quite clearly that it was rather infrequently that aged individuals created the impression, in presumably astute observers, that *they* were less than moderately intelligent or had less than moderately good memories Although data of this nature cannot reasonably be employed to controvert the indications of controlled observations, they

certainly suffice to challenge seriously the notion that the belief in the intellectual impairment and memory deficit of the aged individual enjoys the support of the *overwhelming agreement of human experience*

SHORT TERM MEMORY

Apparently because she deemed it somewhat precipitous of Wechsler to conclude from the results on two memory span tests that a general impairment of memory is characteristic of the aging individual, Gilbert (1941) employed, in her study of short term retention, a set of five tests of immediate recall and six tests of not so immediate recall, with two of the latter (paired associates and paragraph recall) being administered both with and without a delay The subjects were 174 persons between the ages of 60 and 69 who were "matched exactly" on the Terman vocabulary test with 174 controls between the ages of 20 and 29 A list of the tests employed appears in Table 14 together with the average scores and other indexes of performance for the two age groups separately Most of these tests were taken from the revised Babcock Test of Mental Efficiency The paragraph was taken from the Stanford-Binet 10 year level In general, the procedures employed by Gilbert are not described in detail

Because in the course of the experiment it appeared that the brightest of the older subjects were not showing as much memory loss as the others, two subgroups consisting of the forty brightest (Terman vocabulary) subjects from each age group, were formed for comparison purposes The results from these subgroups are shown separately in Table 14

The first two columns of the table give the average scores for the two age groups on the several tests for all subjects and for the selected subgroups of bright subjects The third column shows the percentage of the older subjects that equaled or exceeded the mean of the younger subjects in the unselected group The next two columns show the percentage memory loss computed for the older subjects on each of the tests using the corresponding scores of the younger subjects as bases Finally, the standard deviation of scores on each of the tests in each of the age groups are shown in the last two columns

Except for the bright subgroups on the visual and the auditory digit spans, the differences between the age groups were statistically reliable on all the tests. "Retention of paired associates is one of the tests on which older persons show greatest decline We see that not only is the formation of entirely new associations harder for older than for younger persons but the retention of these associations is even more difficult" (Gilbert, 1941, p 78) "There is a slightly greater loss for retention than for immediate recall" (p 85)

These statements and certain aspects of the results seem to suggest that the older subjects suffered more from delay of recall than the younger ones did, that is, they were less capable of retaining acquired material It seems, however, that this impression is wholly dependent upon disregarding the acquisition indexes Thus, although it is true that the older subjects showed a 54 6 per cent deficit relative to the young (unselected groups) on the delayed recall of paired associates, it is important to note that they had a 58 7 per cent deficit on the immediate recall of this material They may, therefore, have recalled less on the delayed test simply because they learned less during the acquisition trials, but, relative to what they had acquired, their delayed recall was superior to that of the younger subjects The situation is very similar for the recall of the paragraph and for both of these retention tests among the selected subjects It is unadvisable to evaluate the results on the Turkish English vocabulary, first, because there are no acquisition indexes and, second, because the procedure seems to have been somewhat curious, as the following statement suggests "Instead of remembering the actual Turkish words, many indi

viduals remember the position of the words they underlined when first presented with the series A kinaesthetic memory seems to play a part (Gilbert 1941 p 79)

This study indicates rather clearly that, for a variety of materials the older subject acquires much less material from a short presentation than the younger one does but it does not provide any evidence to the effect that he retains acquired material less well Thus it offers evidence concerning memory only insofar as memory is inextricably associated with evidence of acquisition

SINGLE SUBJECT LONGITUDINAL STUDY OF RETENTION

Madorah E Smith (1935, 1951) has reported an interesting longitudinal study of her own retentiveness From the age of 8 to 13 years she studied the answers to the 107 questions in the *Westminster Shorter Catechism* by distributed practice and review until it was believed that she could recite all of them in order at one sitting without error More than 20 years after the last incidental recall of this material, she tested her memory of it for the first

TABLE 14*

SCORES OBTAINED BY TWO AGE GROUPS OF SUBJECTS ON A BATTERY OF STANDARD MEMORY TESTS

Test	Average All Ss	Average 40 Best	Per Cent Overlap All Ss	Per Cent Loss All Ss	Per Cent Loss 40 Best	SD All Ss	SD 40 Best
Digit—Visual							
20 yr	8 21	9 28				1 11	0 89
60 yr	7 51	8 80	42 0	8 5	5 2	1 45	1 12
Digit—Auditory							
20 yr	6 87	7 28				1 15	1 28
60 yr	6 06	6 78	33 8	11 8	8 4	1 15	1 15
Digits—Reversed							
20 yr	5 53	6 40				1 35	1 45
60 yr	4 36	5 20	26 5	21 2	18 8	1 22	1 06
Sentence Repetition							
20 yr	16 76	19 35				2 72	1 80
60 yr	13 29	17 35	27 0	21 3	10 3	2 09	1 94
Knox Cube Test							
20 yr	8 71	9 38				1 95	1 59
60 yr	6 44	8 03	20 0	26 2	14 4	2 15	2 17
Paragraph—Immediate							
20 yr	10 85	12 25				3 22	3 16
60 yr	6 32	9 73	12 0	41 8	20 6	3 33	3 29
Paragraph—Delayed							
20 yr	14 01	16 50				3 47	2 47
60 yr	9 16	13 43	17 0	39 7	18 6	4 47	3 23
Designs							
20 yr	13 54	15 20				2 65	1 30
60 yr	7 32	11 48	13 9	45 9	24 6	4 48	3 78
Paired—Associates Immediate							
20 yr	6 27	7 38				1 91	1 28
60 yr	2 59	4 70	10 0	58 7	36 3	2 09	2 24
Paired—Associates Delayed							
20 yr	7 51	8 25				1 75	1 23
60 yr	3 41	5 75	10 9	54 6	30 3	2 38	2 24
Turkish English Vocabulary							
20 yr	7 49	8 53				1 73	1 14
60 yr	2 97	5 80	12 0	60 4	32 0	2 58	1 36

* Source Adapted from Gilbert (1941)

time (Smith, 1935), and then, at the age of 60, 16 years after the first retention test, she attempted a second recall (Smith, 1951) "This time [second recall] 53 answers were repeated perfectly as against 54 previously [first recall], 39 instead of 44 with very little prompting [that is, with a cue of no more than two words given], and 15 instead of 9 requiring more prompting' (Smith, 1951, p 337)

It is clear that the results of these observations left the subject and investigator under the impression that she had suffered no appreciable deterioration of memory up to her sixtieth birthday It is hoped, of course, that further information concerning the retention of these materials will appear in 1966 Meanwhile the interested reader can secure less formal but more detailed information concerning this investigator's memories of daily life experiences over similar time intervals (Smith, 1952)

Animal Studies

SHORT TERM MEMORY TEST

Maier (1932) in one of his early studies, described an interesting test of what may be interpreted as short term memory and, although he did not investigate the age range that is of particular interest in the present context he did encounter unexpected and relevant results by finding that mature but not superannuated rats (more than 120 days) were superior to younger ones (50-75 days) on this test His apparatus consisted of three small differentially marked tables connected by an elevated, Y shaped runway as shown in Figure 16

To begin the test the animal was allowed to explore the situation for an unspecified time, was fed on one of the tables, and from time to time was disturbed in his feeding to prepare him for the test proper On a regular run the subject was placed on an arbitrarily chosen table and allowed to begin eating It was then removed to one of the two remaining tables The question, of course, was Would the rat return directly to the goal table, or would it go up the 'wrong' arm of the Y? From trial to trial the goal and starting tables were selected from a prearranged randomization schedule, so that there was no fixed response pattern associated with success The animal, in order to make better than chance choices, evidently had to remember, on some trials at least, which table he had just been transferred from (short term memory) and how to get to it (relatively long term memory) As the principal index of mastery, Maier (1932) employed the number of correct choices minus the number of wrong choices divided by the total number of choices, $(R - W)/(R + W)$

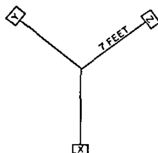


FIG 16—Schematic ground plan of Maier s memory test for rats (After Maier 1932)

Three sets of observations were made (*a*) a cross sectional study in which a group of young rats (50-75 days) was compared with a group of older ones (120 days and over), (*b*) a longitudinal study in which a group of rats was tested once when young (60-80 days) and then again when adults (120 days or more), and (*c*), presumably as a check on the transfer effect in the longitudinal study a group of adults (120 days or more) was tested twice with an interval of two weeks between tests The data from these observations are shown in Table 15

The cross sectional study shows a marked superiority for the adult animals and the longitudinal study indicates a smaller but considerable superiority in the same direction The transfer check shows no gain and thus suggests that the higher score obtained

TABLE 15*

NUMBER OF INCORRECT CHOICES MADE ON A MEMORY TEST BY INDIVIDUAL RATS OF TWO AGE GROUPS IN A CROSS-SECTIONAL STUDY AND AT TWO DIFFERENT TIMES IN TWO LONGITUDINAL STUDIES

	EXPERIMENT I (CROSS-SECTIONAL)		EXPERIMENT II (LONGITUDINAL)		EXPERIMENT III (LONGITUDINAL)	
	50 Days	120+ Days	60–80 Days	120+ Days	Adult	Later
	1	3	2	1	1	2
	3	6	2	1	1	2
	3	3	2	4	0	2
	7	0	3	0	3	3
	8	3	2	3	3	3
	4	3	2	3	3	0
	6	4	3	3	0	1
	1	1	4	1	0	0
	3	0	2	1	1	2
	6	2	7	0	1	1
	2	1	1	0	3	1
	4	1	0	1	1	1
	4	0	3	3	3	1
	8	0	1	1	1	2
	5	0	6	0		
	4	1	0	2		
		1	2	1		
		2	2	0		
		2	0	0		
No trials	12	18	12	15	15	15
Av no correct	7 6	16 3	9 7	13 7	13 5	13 5
Score	26 5	80 7	61 4	82 4	80 0	80 0

* Source Adapted from Maier (1932a)

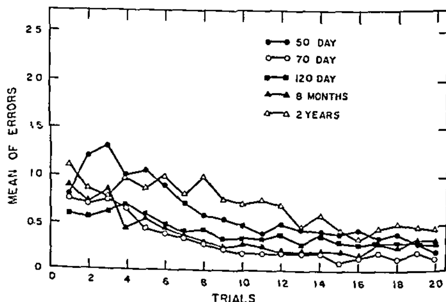


FIG 17 —Mean numbers of errors for several age groups on successive relearning trials in a Carr Maze after 70 days without practice (After Stone, 1929a)

by the longitudinal group when adults was a function of age and not of positive transfer from the first test

It is, of course, unfortunate for the purposes of this section that the age range was not considerably extended in these experiments It may well be that the mechanism subserving the function under investigation simply matures later than cer-

senescence These results, however, are certainly provocative, and the fact that for young adults performance is stable on this task suggests that it is a good tool for longitudinal studies of short-term memory in lower animals Although the apparent stability observed in the transfer check may be dependent upon the high degree of mastery, that is, $(R - W)/(R + W) = 80$ on the initial test, it is not at all clear that this detracts greatly from the value of the problem for testing the hypothesis in ques-

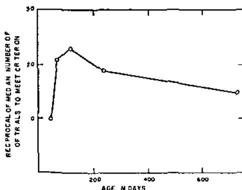


FIG 18—Reciprocals of the median numbers of trials required by several age groups to relearn the Carr Maze (Adapted from Stone 1929*a*)

tion, and it certainly seems possible to manipulate the degree of mastery by increasing the number of choices

RELEARNING OF CARR MAZE

It will be observed from Table 8 *that* Stone performed several relearning experiments, the data from one of which are presented in Figure 17 In this study several age groups of rats worked at relearning a maze 70 days after their original learning to a criterion of not more than one error in three successive trials The figure shows the average number of errors as a function of trial number during the relearning The 2 year old animals here show a marked impairment of retention which is statistically reliable

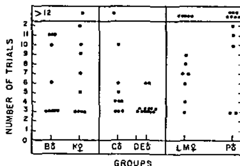


FIG 19—Numbers of trials required by several age groups of rats to relearn a multiple-T maze after about 50 days without practice (After Verzar McDougall 1957)

Age category 1 4–4½ months old
Group B 10 male rats 4½ months old, relearning after 56 days
Group K 10 female rats, 4 months old, relearning after 40 days
Age category 2 11 months old
Group C 10 male rats 11 months old relearning after 56 days
Group DE 13 male rats 11 months old relearning after 40 days
Age category 3 22 31 months old
Group LM 12 female rats 22 months old, relearning after 40 days
Group P 12 male rats 26–31 months old, relearning after 60 days

In Figure 18 the reciprocals of the median number of trials required by the several age groups to meet the criterion of relearning are shown as a function of age in days This figure also reflects a marked impairment of retention with age It may be interesting to note that this function has a form similar to those typically portraying the deterioration of mental functions in man

CROSS SECTIONAL AND LONGITUDINAL STUDY OF MEMORY

Verzar-McDougall (1957) has made a *rather thorough study of retention in her* rats by the relearning method Figure 19 represents the results of some cross sectional observations of the effects of a delay

of about 50 days between the termination of original training and the beginning of relearning for several groups of rats that learned at different ages In the relearning test the animals were given one trial a day for 12 days or until they achieved the criterion of not more than three total errors in three consecutive runs

It is customary in relearning evaluations of retention to provide some sort of savings score (Munn 1950 p 290), but Verzar McDougall (1957) presents instead, the distribution of the number of trials required to relearn by those animals that re learned in twelve trials or less and the

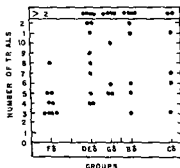


Fig 20—Numbers of trials required by the members of several age groups of rats to relearn a multiple-T maze after various intervals without practice (After Verzar McDougall 1957)

number of animals in each age group that failed to relearn within twelve trials These data are given in Figure 19 for several age groups Since the performances of individ ual animals are not identified, it is impos sible to refer these retention scores to orig inal learning performances, and this, in turn, precludes the calculation of gains Decision as to which animals failed in both tests, which learned but failed to relearn, and which "relearned" in spite of having failed to "learn" cannot be made

Verzar-McDougall bases her evaluation of the retention of the several age groups largely on the relative frequency of perfect recall and on the relative frequency of failure to relearn in twelve trials (1957, p 75) From these considerations she con cludes that "the ability to recall the maze after an interval of 40–60 days is consid erably worse in the old rats of 22–31 months than in the young adults of 11–12 months or in the young growing rats of 4–4½ months" (1957, p 74) Similar data for other groups and other delay intervals, presented in Figure 20, lead to similar conclusions

It is difficult to know what to think of some of the comparisons made from these data For example, Verzar McDougall com pares Group F with each of the remaining groups, in spite of the fact that three (DE, B C) of them were relearning for the sec ond time rather than the first time and two of them were relearning 9½ months after the last test instead of 6 months after it Comparison between F and G, which super ficially appears good, is somewhat marred by the fact that there are no data on the original learning of Group G This figure is interpreted as indicating a superiority for animals that learned while young and re learned early

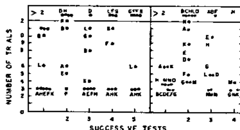
The data from a longitudinal study of retention in two of Verzar-McDougall's groups, with the performances of individual animals identified, are presented in Figure 21 It may be of interest to note that, of *the nineteen animals* surviving the next to-last test, (1) there were four that did well on the original learning and on all the relearning test (Group B, rat A, Group DE rats G, D, and M), (2) there were six that showed *reversible memory losses* by later performances that were superior to earlier poor ones (Group B, rats H, K, and L, Group DE rats L, K, and N), (3) there were seven that showed more or less progressive loss (Group B, rats E and F, Group DE, rats A, B, F, E, and H), and (4) there were two that were poor through out the several tests (Group B, rats G and B) Since neither repeated demonstration of good memory nor repeated demonstra tion of poor memory can be accepted as evidence of impairment, and since reversi ble memory loss can hardly be considered consistent with the hypothesis of progres sive deterioration of memory with age, only about 37 per cent of the animals gave per formances consistent with the notion of an

age impairment. It seems important to realize that, when we have detected a difference in the mean performances of two age groups, this may reflect deterioration in no more than 37 per cent of the old population and that some of this "deterioration" may be reversible. This sort of result emphasizes the importance of attempting to discover some factor responsible for the "age deficit" that is somewhat more specific than chronological age. It is highly desirable to know how the individuals of the 37 per cent that deteriorated differ from those of the 21 per cent that remained definitely good in spite of the passage of time and from those of the 32 per cent of the population that showed only transient and not progressive loss.

V. Transfer and Interference

"Conceivably the learning of one act might facilitate or hamper the subsequent learning of another act, and might affect favorably or unfavorably the retention of an act already learned or its execution (recall). The many possible varieties of interaction have not all been examined experimentally" (Woodworth 1938, p. 76). The notion of transfer, as employed in this section, refers to any interaction between learning processes, between learned reactions, or between such processes and such reactions. When the interaction has apparently favorable effects, the transfer is said to be positive; when the effects are unfavorable, the transfer is negative. It is usually assumed that in any particular situation there may well be factors operating which severally tend to induce both types of transfer so that the final indication in one direction results from a process of summation. It is very difficult to differentiate between *negative transfer* and *interference*, but it is customary to distinguish two types of interference, associative and reproductive, depending upon whether it is the acquisition or the execution of an act that is interfered with.

The notion that, as a person ages, he becomes increasingly susceptible to interference is the principal alternative to the degeneration hypothesis as an explanation of the impairment of memory and the ability to learn that is allegedly associated with the process of aging. There is, of course, little reason why interference and degeneration should be considered exclusive alternatives rather than conjunctive factors contributing to the deficit in question. These matters, however, are more properly discussed elsewhere (below, chap. xviii).



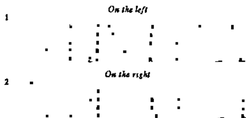


FIG. 21.—Numbers of trials required to relearn a multiple-T maze at several times during the life-span: a longitudinal study of memory in rats. (After Verzar-McDougall, 1957.)

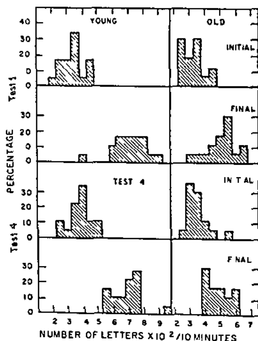
Each rat's score is marked with a letter so that the individual performances can be followed.

WRITING WITH THE UNFAVORED HAND

Learning to write with the unfavored hand seemed an especially informative task with which to study transfer-interference hypotheses, because "when one changes the hand in writing, not only do none of his old habits of movement fit the new demand, they are distorted in a complicated way. Nevertheless, the mere general control given by knowledge of the desired appearance and by vision enables the adult learner to counteract tendencies to write in a mirror fashion, and to establish rather quickly a new hierarchy of habits" (Thorndike *et al.*, 1928, pp. 37-38). In these

statements Thorndike calls attention to an interesting summation of positive transfer (visual standards and guidance) and interference (mirror reversal of movements)

Thorndike used university students (seventeen less than 35 years old, sixteen more than 35, maximum age 57) in this study They were given 15 hours of prac tice, divided into ninety 10 minute periods, with 5 minute rests interspersed between



from Thorndike *et al*, 1928)

trials Four practice trials or tests were given daily Tests 1 and 3 consisted of writing the words "one,' "two," , 'twenty," the days of the week, the months of the year, and seven lines of poetry, Tests 2 and 4 consisted of copying material from the *Journal of Educational Research*

In Figure 22 the relative frequencies of various rates of writing in the two age groups are shown for the first and last performances on Tests 1 and 4 It is important to note that both groups showed positive transfer, since "the general fact remains that somehow the adult starts in writing with the wrong hand with nearly as great facility as the child of eight or nine has in writing with the right after two years of schooling" (Thorndike *et al*, 1928, p 38) Comparison of performances in the initial tests suggests that the older subjects were only slightly inferior to the younger ones with respect to this transfer, in spite of the fact that it is based on a rate index Com paring initial and final tests for the two age groups reveals a probably reliable dif ference in gains in favor of the younger subjects, but, although they learn to write faster, they do not learn to write better than the older subjects, who showed a slightly greater gain in the quality of their unfavored handwriting as evaluated by the Thorndike Scale In general, the gains in quality and speed manifested by both groups were about equivalent to the prog ress from Grade II to Grade IV

MATERIALS OF DIFFERENT INTERFERENCE VALUES

Ruch (1934) reported an experiment de signed to test the notion that the amount of difference observed between the learning abilities of young and old subjects will depend upon the extent of the reorganiza tion of long established reaction patterns that is required by the particular tests employed Thus the two rotor pursuit tasks, described above, one employing direct vi sions, the other mirror vision, apparently differ greatly with respect to the extent to which they require reorganization of hab itual reaction patterns Similar differences were assumed to exist between three types of verbal materials that Ruch (1934) had his subjects study as paired associates In this experiment there were fifteen presenta tions of each of three ten item lists of the following types

(1) Word associates, e g, house—visit
(2) Nonsense equations, e g, $R \times S = Q$
(3) False equations, e g $6 \times 3 = 5$

They were presented to three age groups, 12–17 years, 34–59 years, and 60–83 years,

in the order given on the same day and after having completed the mirror-vision, rotor pursuit task Since this is the order of difficulty of the verbal tasks as determined by the results, it is at least possible that the differential reactions of the age groups to these tests were a function of differences in cumulated fatigue

The data are reported in terms of the number of correct responses totaled over the fifteen trials and averaged for each age group It will be noticed, of course, that such indexes are not well designed to provide information concerning learning in the sense of improvement with practice, since the observed differences between age groups could easily be the result of a cumulation of a small but constant difference between the groups Although such a result would indicate an initial advantage for the younger subjects, it would also suggest that after the first trial the older subjects were able to derive as much advantage from training as the younger subjects did

Because this experiment has been repeated in a fashion that permits more detailed analysis of the results, only Ruch's principal conclusion is considered at the present time "The major conclusion of this study is that old age in man brings a deterioration in learning ability which is not general but depends to a significant extent upon the nature of the material learned" (1934, p 275) This is not to be interpreted as suggesting that the old did as well as the young on some tasks but simply that the difference in favor of the young was smaller on some tasks than on others

Korchin and Basowitz (1957) in an abbreviated adaptation of Ruch's (1934) experiment employed two contrasted age groups sixteen institutionalized subjects with an average age of 78 1 years and sixteen physicians and nurses with an average age of 26 8 years These groups were equated for performance on the Vocabulary Test of the Wechsler Bellevue Scale Ruch's verbal materials, word associates, nonsense equations, and false equations were used, but the number of items per list was reduced from ten to eight, and the number of repetitions of each type of list was decreased from fifteen to six, to avoid fatiguing the older subjects It is not clear whether or not the three types of list were presented in the same fixed order employed by Ruch

TABLE 16*

MEAN NUMBER OF ITEMS PER SUBJECT CORRECTLY ANTICIPATED BY TWO AGE GROUPS ON THREE PAIRED ASSOCIATES TESTS

AGE GROUP	No	MEAN AGE	TEST		
			Word Associates	Nonsense Equations	False Equations
Young	16	26 8	44 19	25 00	24 81
Old	16	78 1	30 38	7 43	7 19

* Source Korchin and Basowitz (1957)

Table 16 shows the mean number of items correctly anticipated during the six training trials by the two age groups separately These data fail to corroborate Ruch's finding that the "interference materials" (false equations) are more difficult than the nonsense materials and produce greater differences between young and old subjects Because the entries in this table are based on the sum of the items recalled during the entire training series, they are incapable of providing information concerning learning in the sense of improve

ment as a function of practice, and, as in Ruch's experiment these results can be understood in terms of a trial by trial cumulation of a constant difference between the two age groups

This question is considerably elucidated by Figure 23, which shows the average number of items correctly anticipated on each of the six trials with the three types of materials by the two age groups There is no doubt that with each of the three types of materials the younger subjects anticipated more items than the older subjects

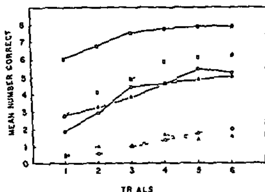


Fig 23 —Average number of correct responses on three paired associates tests on successive trials by two age groups The curves from the younger subjects are drawn in *solid lines* for the older ones in *broken lines* The three tests are symbolized as follows □ word associates ○ nonsense equations △ false equations (After Korchin and Basowitz 1957)

on the first test trial This is a question of initial score may well be designated as memory span and is quite obviously an aspect of learning in which the younger subjects were markedly superior to the older ones This however, is not the only important aspect of learning but rather, has been treated traditionally as an annoying contingency to be avoided whenever possible Interest has typically been concentrated on the improvement in performance that occurs *after* the initial test. Figure 23 makes it quite clear that the very impressive difference between age groups exhibited in Table 16 are due largely to initial differences and only slightly, if at all, to the fact that the younger subjects improved more rapidly with subsequent practice than the older subjects did It can be observed, for example, that on the word associate test the difference between the scores for the young and old subjects decreased as a function of practice This may have been due, in part at least, to the fact that the younger subjects were approaching the ceiling very closely after the first three trials, whereas the older subjects still had considerable opportunity for improvement. But on the other two lists the ceiling effect was not encountered and it is not clear that the learning curves for the two age groups are not parallel The authors do not comment on this point, and the numerical data for testing are not available so the question must remain unsettled We do not know if the old improved less quickly with practice after the first trial than the young

due to "no response," those due to the use of a response item belonging to the series but "correct elsewhere," and so-called 'random responses," that is, the use of response items that do not occur anywhere in the series being studied The relative frequencies of these various types of error are shown for the several sets of materials and age groups separately in Table 17 It is quite clear from these data that when the young subject failed to produce the correct response, he was more likely to produce some response rather than no response at all, whereas the tendency was quite the reverse with the older subject (i e, he was much more likely not to respond than to

ι e you g subject

due to no response was relatively high during the early trials but decreased rapidly with training in favor of responses that were "correct elsewhere" in the series The older subjcts, on the other hand, had a very high proportion of 'no response errors

throughout the practice—as high as 92 per cent on the last trial

Korchin and Basowitz (1957) suggest that the following three factors jointly determine the older subject's marked tendency to refrain from responding (1) the older subject is more cautious and prefers an error of omission to an error of commission, (2) the processes of "perceiving judging recalling responding' require more time for the older subject than was allowed by the pacing schedule employed, and (3) 'for the older person learning may principally involve the association of *discrete* stimulus response combinations and unlike the younger person, may not include a prior stage in which the response items are first learned as belonging *somewhere* in the series, before they are attached to particular stimuli' (p 68)

TRANSCRIBING CODE

In the studies just reviewed it has been assumed that negative transfer or interference influenced the test results through the perseveration of behavioral tendencies induced and supported by a lengthy accumulation of experiences that are normally associated with everyday living and consequently quite beyond the control of the experimenter In the following studies reaction tendencies presumably inducing transfer are created and reinforced by the experimental procedure It is usually conceded that this design gives the experimenter more precise control over the character and strength of the interfering habits

Thorndike *et al* (1928) gave adult prisoners training in code substitution by having them transcribe words into numbers according to the simple transformation

$$\begin{matrix} a & b & c & & z \\ 1, & 2 & 3 & & 26 \end{matrix}$$

for eight 3 minute practice periods after which a recall test for incidental memory of the code was administered One week later additional tests and four practice periods were given on the same materials in order to secure relearning data After completing this practice the subjects were required to reverse the direction of transcription, that is, they were given materials in number cipher and required to substitute letter equivalents for four 3 minute practice sessions Two days later eight 3 minute practice periods were given with a new code in which the number transform of any given letter was its ordinal position from the end of the alphabet

$$\begin{matrix} a, & b & c, & & , z \\ 26 & 25 & 24 & & 1 \end{matrix}$$

In the last two tasks interference was to be anticipated, but, of course, the procedure provided no means of measuring its effect, since no control groups were employed

TABLE 17*

RELATIVE FREQUENCY OF THREE TYPES OF ERROR FOR TWO AGE GROUPS ON THREE PAIRED-ASSOCIATES TESTS

Test and Age Group	Total Errors	Relative Frequency		
		No Response	Random Errors	Elsewhere
Word associates				
Young	61	62	07	31
Old	273	83	01	16
Nonsense equations				
Young	368	45	07	48
Old	649	92	01	07
False equations				
Young	370	30	25	45
Old	653	75	07	18

* Source Korchin and Basowitz (1957)

The results of this experiment are shown in Figure 24 in terms of the average number of letters transcribed per minute in successive practice sessions by three age groups It will be noted that the improvement in performance, as judged by the slopes of the suggested functions, was very similar in the three age groups Similarly, the losses after a week without practice were about the same, and the rates at which the three groups improved during retraining were very similar Moreover,

cal transformations however, a marked superiority in positive transfer can be obtained for the youngest subjects Finally, the adjusted scores return to an indication very similar to that obtained with the percentages The covariance analysis of the transformed scores indicates that the superiority in absolute amount of transfer enjoyed by the older subjects when raw scores were considered became a reliable superiority in favor of youth when the scores were transformed to reciprocals and adjusted for vocabulary and rate of original learning The broader implications of this phenomenon are discussed by Botwinick (chap xxi)

TABLE 19*

AVERAGE LEARNING RATE AND RECALL SCORES FOR PAIRED ASSOCIATES TESTS IN SEVERAL AGE GROUPS

	AGE GROUP		
	20 29	40 49	60 72
Mean raw scores			
Original learning	14 8	19 7	23 3
Interpolated learning	10 9	15 2	17 7
Gains	3 9	4 5	5 6
Recall	4 3	4 0	3 3
Transformed scores			
Orig nal learning	79 98	59 65	53 30
Interpolated learning	116 88	80 88	72 30
Gains	36 90	21 23	19 00
Adjusted scores			
Original learn ng	85 78	59 18	48 10
Interpolated learning	112 23	83 48	73 81
Gains	26 45	24 30	25 71
Recall	3 90	4 14	3 52

* Source Adapted f om Gladis and B aun (1958)

The relative susceptibility of the various age groups to retroactive interference is presumably reflected by the differences in the number of items recalled on the first relearning trial When analysis of covariance, with all appropriate adjustments, was performed on the raw scores the observed differences in favor of younger subjects were found to be unreliable When adjustments for learning rates were not made, the observed differences in favor of the younger subjects were reliable It seems worth pointing out, however, that, in order to justify conclusions concerning retroactive interference, it would, according to the traditional paradigm, be necessary to have control subjects (not given interpolated work) for each age group, since it is at least possible that some loss in recall not attributable to the specific interpolated work here employed, might occur and that the amount of such loss might be different for the several age groups But, in spite of the fact that the data presented in Table 19 fail to establish or measure the operation of retroactive interference in this experiment, its operation can perhaps be inferred from the fact that there was a significant effect of similarity of interpolated work on amount of recall This, of course, is consistent with the notion that retroactive interference was operating But it does not provide a basis for estimating the amount of its effect in the three age groups, nor does it supply any support for the notion that the extent of its effect was inversely proportional to the numbers of items recalled by the several groups, which, incidentally, seems implicit in the conclusion drawn by the authors

It appears reasonable, nonetheless, to interpret this experiment as indicating a difference in learning ability in favor of the young and as suggesting that age differences in transfer seem small even though possibly reliable, depending on the sort of adjustments made It also suggests that age differences in retention in a situation in which retroactive interference is probably operating are small but possibly *reliable*, depending, again, on the test that is applied

An Animal Study

Although transfer of training and interference have been intensively investigated for many years in the field of animal learning, the effects of age on these aspects of modifiability remain almost completely unexplored In most of Stone s studies (*1929a*, *1929b*) the animals employed were subjected to a rather lengthy series of

learning problems, and it is highly probable that experience with the earlier problems influenced performance on the later ones in some fashion, but these effects were not systematically studied The following seems to be the lone exception

COUNTERTRAINING ON DISCRIMINATION PROBLEM

In order to compare the readiness with which old habits can be broken up and antagonistic ones can be acquired at various ages, Stone (1929*b*, pp 167–72) subjected three age groups from the discrimination learning experiment described in the section on acquisition to a long series of countertraining trials *It will be recalled that* these animals were formerly trained to turn, at each choice point regardless of its serial position, in the direction of an illuminated window After forty trials of this training, when performance had become quite stable, three age groups were required to turn away from the illumination and toward a dark window which they had formerly learned to avoid All animals were

TABLE 20*

MEDIAN NUMBER OF TRIALS REQUIRED TO ACHIEVE A CRITERION FOR SEVERAL AGE GROUPS ON A COUNTERTRAINING TASK IN A LIGHT DISCRIMINATION PROBLEM

Age Range (in Days)	No	Per centage Failing	Median No of Trials	Probable Error
51–110	21	6	35	3 32
246–305	19	15	46	4 14
771–830	7	43	54	

* Adapted from Stone (1929*b*)

given sixty trials on this new problem The criterion of mastery employed was three consecutive errorless trials, but not all animals learned to this criterion within the practice allowed

Table 20 shows, for each age group, the percentage of animals failing to meet the criterion, the median number of trials required to meet it, and the probable errors of these medians Although the observed difference between the youngest and the oldest group was not reliable, these data suggest that age decreased the ability to make the required reversal, and this indication was corroborated by the error function of trials shown in Figure 25, where the

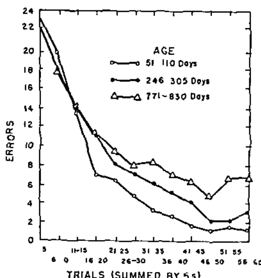


FIG 25 —Mean numbers of errors on successive groups of five trials made by three age groups of rats during countertraining on Stone s discrimination problem (After Stone, 1929*b*)

average numbers of total errors per animal in successive groups of five trials are shown for the three age groups separately

Stone (1929*a*, p 169) reasoned that 12 5 such errors, should represent chance performance On this basis, the considerably higher error scores obtained on the early trials would be interpreted as negative transfer, in which there were no apparent age differences The fact that the three age contours were about parallel until this level of achievement was reached was interpreted to mean that the old habit was broken up at about the same rate by the three age groups The fact that the error curves began to diverge markedly beyond this point was interpreted as indicating that the older animals were distinctly inferior with respect to the rate at which they

acquired the new habit This effect of course would also be considered negative transfer and should probably be distinguished from the breakdown process if for no other reason than that the two processes appear to be differently affected by age

VI Discussion

A review of the experimental studies of the effects of aging on the ability to learn yields the impression that two types of difficulty impair the interpretability of their results One is due simply to a failure to follow conventional procedures and methods of reporting results This source of ambiguity is easily eliminated The other type of difficulty however is more intrinsic to the specific problem and appears to derive from the fact that a number of factors that are known to exert marked influence on learning performances are also known to be related to age in such a fashion as to result in test differences in favor of younger subjects Motivation speed of performance and physiological status are prominent examples of such factors and although they are known to influence learning indexes they are traditionally differentiated from the processes of modifiability themselves and are regarded as highly relevant variables which must be controlled in any satisfactory study of learning The special problems that these relations create in gerontological psychology appear to derive from the fact that it is not clear how these variables can be manipulated independently of age in order to determine to what extent they suffice to explain observed differences in learning scores that have been interpreted as being due to age related changes in the processes of modifiability

Concerning motivation it will be recalled that there is considerable evidence indicating that learning indexes can be strongly influenced by the degree of motivation active during the acquisition trials (McGeoch and Irion 1952 chap vi) and it certainly seems unlikely that the average septuagenarian can achieve as much tolerance as a young subject toward the usually unengrossing often monotonous tasks characteristic of conventional and psychological tests Unfortunately however, to submit such an opinion to empirical verification is no simple matter A long history of frustrated effort to manipulate human motivational states convincingly has left the impression that rewarding experimentation in this field is extremely difficult With respect to infrahuman subjects there is good reason to believe that the degree of motivation consequent upon a given duration of food deprivation is directly related to the growth rate at various ages and thus is inversely related to age Indirect empirical evidence to this effect is available from the observation that a given duration of deprivation affects to an extent inversely related to age certain physiological functions that are commonly accepted as the primary antecedents of the hunger drive Finally to the extent that amount and rate of activity can be accepted as indicators of the degree of motivation there is direct empirical evidence for the belief that the degree of motivation associated with a given amount of deprivation is inversely related to age It is very far from clear that there is some adequate method for dealing with this problem Though Stone s adjustment certainly appears to be in the correct direction there is no accepted way of deciding when an appropriate differential deprivation has been achieved for example we do not know that Stone s schedules did not result in higher motivation in the aged animals than

ability to learn can be more d rectly studied in lower animals than in man According to Hovland (1951) this seems to be the case in general

tween motivation and learning This is due in part to the fact that whereas with animals we can subject to experimental control such basic

drives as hunger, thirst or sex, we must in the case of human subjects, deal with complex acquired motives that are little understood [p 629]

Like motivation, speed of performance is intimately related to modifiability and this natural association leads to certain complexities of interpretation which probably could be somewhat simplified by procedural precautions There is an impressive amount of empirical data indicating that age brings with it a marked speed decrement which affects learning indexes as well as a large variety of performances that are well practiced and consequently quite independent of ongoing learning processes Owing to this pervasive effect of the speed deficit, observed age differences in time related learning scores can quite reasonably be assigned to the slowing down of some rather peripheral receptor or effector processes essential to the performances to be learned The feasibility of such an interpretation, however, should not be allowed to obscure the possibility that the speed deficit has an effect on, or is itself a manifestation of, deteriorating central integrative or cognitive functions intrinsically related to the processes of modifiability It seems important, therefore, to achieve an evaluation of the relative contribution of speed factors extrinsic and intrinsic to the processes of modifiability by systematic variation of temporal factors as controlled variables rather than accepting them as dependent variables assumed to reflect differences in learning ability

Throughout this review discussion of the selection of subjects has been sedulously avoided, not because the problem was believed to be of minor importance, but because it was felt that the investigators had all reluctantly made the best possible compromise with the practical exigencies under which they worked It is, of course, to be regretted that many of the subjects, taken to represent the aged population in these studies were patients in institutions ostensibly caring for the indigent and physically debilitated (Gakkel and Zinina, 1953, Korchin and Basowitz, 1957) Comparing the performances of such subjects with those of their nurses and physicians, even when equated for vocabulary performance, is bound to occasion considerable misgivings, if for no other reason than that indigence and ill health are likely to engender psychological states detrimental to learning

On all of these points there is available to the investigator a philosophical position which, for want of a better term, might be called "clinical" and according to which the ambiguities mentioned above do not create difficulties at all They do not challenge the fact that there are detectible age-related impairments in the ability to learn, they simply explain them They are the natural causes of learning impairments and, as such, are not only legitimate but necessary variables in any study of the effects of aging Thus the observed decrement in motivation and drive with age is regarded as the cause of a real deterioration in the learning procéss per se Moreover, since a speed deficit is of great practical importance in everyday life and is apparently characteristic of aging, it can be argued that to eliminate time constraints from learning evaluations would lead to an undesirable degree of artificiality and to an underestimation of the amount of impairment associated with aging. Finally, indigence and ill health may be considered characteristic of old age in the sense that their relative frequencies in aged populations are presumably higher than in the population as a whole, so that selecting active and healthy subjects to represent the aged population creates a biased sample

It is extremely difficult to weigh the kernel of truth and justice in this practical philosophy, but it seems certain that it should not be carried to the point of insinuating that it is unessential and probably unimportant to determine whether or not there is, associated with aging, an impairment of the ability to learn that cannot be attributed to a lack of effort, to a speed deficit, or to the existence of detrimental

psychological states induced by indigence or ill-health

It is quite true that, while admitting the cogency of the arguments proposed by his colleagues who are primarily concerned with application, the generalist, systematist, or theorist deals almost exclusively with highly idealized organisms, artificial conditions of observation and hypothetical constructs for which he claims no actuality He does this, however, in the firm conviction that such artifices facilitate a conceptual separation of variables that exist in nature only in inextricable confusion The history of science repeatedly reinforces the hope that the sagacious synthesis of hypothetical constructs from such conceptually isolated variables will lead to a more lucid and even more effective comprehension of the phenomena involved than would be possible without the artificiality in question Thus, if it were systematically established that all, or most of the aged individual's learning difficulties are due to a lack of motivation, to indigence, to ill health, and to slowness, the direction of applied research on aging could be chosen with much greater confidence than would be justified at present The data currently available do not provide an adequate basis for deciding whether or not the motivation–speed–indigence–ill health syndrome can be accepted as a sufficient explanation of the observed age differences in learning performance

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XX

Intelligence and Problem-solving

HAROLD E JONES

I INTRODUCTION

When we study human intelligence in terms of the life span we become aware of the fact that mental abilities like physical structures and functions are subject to both positive and negative effects of aging In the first two decades the effects are chiefly positive and are defined in terms of growth or maturation In later maturity negative changes are apparent with progressive age reductions in functional efficiency

This basic pattern is of course subject to rate modifications by extrinsic factors The nurturant and supportive aspects of the environment may range from an optimum to extreme restriction Stimulation and differential incentive and learning and differential practice exert degrees of influence both on the rate of early development and on the rate of later decline

A concept to consider in this connection is that of capacity as related to performance Capacity is a theoretical limit of any individual s performance It is never actually measured since functioning abilities always fall somewhat below the capacity ceiling We may think of individual differences in capacity as determined by organic factors primarily of genetic origin In a given group of subjects who are achieving close to their maximum performance differences would be conceived as highly correlated with capacity differences If these subjects are tested with mental scales appropriate to their education and social background and are consistently motivated in taking these tests the resulting mental scores would also be expected to reflect capacity fairly closely

These ideal conditions are rarely met since individuals vary so widely in the extent to which they fulfil potentials In childhood and adolescence the problem of ability lag is one of retarded growth in achievement—retarded below actual maturation In later years ability lag may consist of a decelerating performance decreasing more rap dly than the actual degree of physical involution In the individual case we can often infer these varying lags and the reasons for them but we can appraise them in only very approximate terms partly because of problems in measurement The abilities reflected in tests may fall below the true ability levels as these in turn fall below capacity

This hierarchical concept of measured actual and potential function (as of a given age) is important for developmental theory as well as for mental test theory We must keep in mind alternative interpretations of obtained age differences In the later years they may be involutional in the cerebral basis of intelligent action secondarily involutional (owing to aging in some other structure or process) a matter of decreasing motivation of interfering habits or some combination of these factors may be involved As if this were not enough we must also deal with possible distortion due to the methods of measurement

It is difficult to discuss aging without betraying a point of view about the data in this field Points of view involve differential emphasis or bias A biological approach is likely to be tough minded, emphasizing the objective facts about behavioral changes, which are conceived as based upon a substrate of physical changes A "client-centered' point of view, on the other hand, is less concerned with predictions from mass data than with the uncertainties of individual progress or retrogression, encouragement can be given to the individual by emphasizing positive rather than negative aspects and by seeking ways in which functions can be maintained and utilized This approach is necessary in the social services for older persons It can be more wisely pursued, however if it takes reasonable account of the general phenomena of aging the facts of life span

Our present task is to consider the evidence, from principal sources on mental abilities as related to age In this discussion we shall be chiefly restricted to the data from standard mental tests and chiefly to the period since *1920* The lack of earlier material on this topic is indicated by the fact that G Stanley Hall's massive volume on senescence, published in 1922 contains nothing of value on mental abilities

Early Studies

Earlier research dealt entirely with the comparison of groups sampled at different ages Inferences as to age change are obviously difficult to make unless the age samplings are comparable but we are often confronted with the loss of subjects, at later ages, due to test resistance If, as is probable, these tend to be subjects who are less competent in tests, the obtained age decline will be less than in a sampling fully representative at all ages Thorndike and

*

of the American Institute of Public Opinion Co-operation was refused by 8 6 per cent in the age group 60 and over and by only 1 5 per cent in the age group 20–30 The age differential in resistance might be expected to be larger in a less disguised testing situation

STUDIES OF 1920

Various methods have been used to obtain homogeneous samples or to allow for sampling differences In one of the earliest reports in the literature Foster and Taylor (1920) compared a group of hospital patients 50 years of age and older, a younger group, and a group of school children, using the Yerkes Bridges Point Scale An age decline was found, which these writers attributed not merely to actual loss in ability but also to lack of practice in certain kinds of activities and to reduced interest or alertness

In studying differential decline of test functions, inequalities in the three samples (whether due to selection or to other factors) were removed by matching the groups for total score When this was done, marked decreases remained in the following four tests (1) word association (number of words in 3 minutes), (2) drawing from memory, (3) putting *three words in* one sentence, and (4) rephrasing dissected sentences

A rate factor as well as mental facility is involved in the first of these tests, verbal problem solving is involved in the latter two Tests which showed an increased score with age were vocabulary (definition of abstract terms), judgment about absurdities, and comprehension of questions In spite of its defects in sampling, this early investigation foreshadows some of the results found in later, more adequate, studies

In another investigation, utilizing the Stanford Binet with a small sample of persons in a home for the aged, Beeson (1920) drew similar conclusions as to the maintenance of vocabulary functions but found relatively large decline in functions involving (1) inventiveness, ingenuity, and imagination, (2) analysis, synthesis, and arithmetic reasoning, and (3) immediate visual memory or perception

ARMY OFFICERS

The first major report based on the testing of complex mental functions among adults of different ages was a memoir published in 1921 by the National Academy of Science This contained the analysis of the Army Alpha Examination data for over 1 700 000 men tested during World War I

The relation to age was examined only with reference to officers Figure 1 gives the

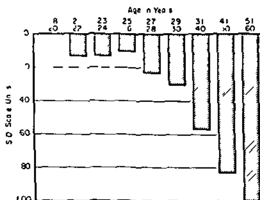


FIG 1 —Age deficits in successive age groups in terms of the mean and standard deviation for ages 18 20

medians for age groups, in terms of the average and standard deviation, for those 18–20 years of age It seems probable that the decrement is exaggerated by selective factors beyond age 30 "The most reasonable surmise is that older officers are selected more on the basis of their specific experience or training, professional or military, and less on native intelligence than are younger officers who have as yet little valuable experience" (Yerkes, 1921, p 813)

THE FIRST STANFORD STUDY (WILLOUGHBY)

It was not until 1927 that a study was published by Willoughby (1927) of a relatively homogeneous group, consisting of families having children aged thirteen in schools in the vicinity of Stanford University Thus for the first time there was the possibility of comparing adults of different ages in an apparently uniform sampling and also of comparing adults with children of the same sample The tests used were a selection from the Army Alpha and Beta, the National Intelligence, and the Stanford Achievement

Figure 2 compares age curves for two of these tests which show different characteristics as to both growth and decline Analogies reaches an early peak and shows a sharp recession Arithmetic reasoning, which presumably involves unequal amounts of practice at different ages, attains a peak in the early twenties and holds up well until age 50 or beyond

Other tests which show patterns somewhat similar to analogies are symbol-digit substitution, symbol series completion, and number-series completion In general, it would appear that tests, such an analogies, which most truly represent abstract intelligence are exceptionally and increasingly hard for adults Tests which reflect accumulated experience, such as vocabulary and arithmetic, may be relatively easy for

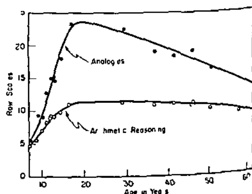


FIG 2 —Curves based on raw scores, for tests showing differing rates of change with age

adults Willoughby's own interpretation was that the functions characterized by sharp peaks are essentially maturational in nature, "acquired more or less as a matter of normal growth and comparatively independent of school training " The sample on which the foregoing is based included 141 children aged 13, 280 siblings, and 190 parents

THE NEW ENGLAND STUDY (JONES CONRAD)

In 1925 H E Jones began the collection of mental test data in a number of New England rural communities This was continued in 1926 by Jones and Conrad, who eventually obtained Army Alpha scores for 1191 subjects between the ages of 10 and 60

The population of the Jones Conrad study living on farms or in small villages, averaged somewhat lower in educational and economic status than in a number of the investigations to be reported in this chapter The average Stanford Binet I Q of the children in these communities was 90 Very few of the adults were in white collar jobs On the assumption that mental abilities are better maintained by mental than by manual activity it would be predicted that decline in later maturity would be more rapid in this group than in urban samples containing a larger proportion of office workers and semiprofessional or professional workers

Approximately half of this sample consisted of adults As in the Willoughby study it is possible to make comparisons of adolescent growth and of adult mental abilities in a homogeneous group Figure 3 presents results in terms of score distributions at the peak of growth and for the three older age groups The difference in means is highly significant, but nevertheless it should be noted that age is a relatively minor factor in determining individual differences The overlapping of the distributions is such that more than one third of the older group exceed the median of the younger, and approximately one in eight reach the score area occupied by the highest quarter of the younger subjects

The question has been raised as to whether the age difference shown above may not be exaggerated by sampling factors, with poorer selections at later ages This possibility can be examined in several ways One is by limiting the comparison of adolescents and adults to family groups, where both parents and at least one offspring were tested with the Army Alpha When this was done, with a total of 335 cases, the improvement in homogeneity of the sample was shown to increase rather than to decrease the adult adolescent differences This comparison provides a check not merely on co operation factors which may influence enrolment in the sample but also on the possible effects of differential migration or differential survival, for, if adults were removed selectively by these factors, their offspring would also be removed or reduced in number

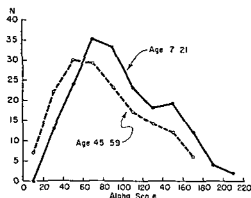


FIG 3 —Distributions of raw scores for an older and a younger group in a homogeneous sample

Another possible check is in terms of the thoroughness of the sampling The testing procedure was organized around the use of free exhibits of motion pictures in community halls—a strong inducement in small rural areas in the 1920 s The samples tested on these occasions were supplemented by a house to house testing Of the nineteen communities in which tests were given, five were intensively sampled, in two of these, adequate tests were obtained for 90 per cent of the total population between the ages of 10 and 60 Fourteen communities were less fully sampled, with supplementary tests limited chiefly to families containing two or more children A comparison showed that in communities such as these a test program based largely on volunteers yields an age decline in in

telligence scores but that the decline be comes more pronounced as the search for subjects becomes more thorough

THE STANFORD LATER MATURITY STUDY (MILES)

In 1930 W R Miles and his associates at Stanford undertook a study of motor, perceptual and mental functions tested in

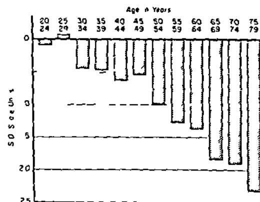


FIG 4 —Age deficits in successive age groups in terms of the mean and standard deviation for ages 20-29

a 2 hour battery The subjects, covering an exceptionally wide age range, were ob tained chiefly through contacts established with lodges and other social groups in two California cities Parts of this comprehen sive research are available only in manu script form (Ph D dissertations in the Stanford University Library)

The mental test used was an abbreviated 15 minute form of the Otis Self administer ing Test of Intelligence Specially printed in large type, it bore the title ' Good Judg ment Question Series," which was thought to be less threatening than a title referring to mental abilities The principal tabular and graphic data for the mental scores are in a 1932 publication

Figure 4 shows age changes computed by the writer on the basis of the mean and standard deviation for the age group 20–29 The decline from 22 5 to 55 is approxi mately 1 S D The drop to below — 2 S D at 75 should be evaluated with reference to the small number of cases at the upper ages and the possible inappropriateness of the test at these ages When the cases are classified into seven intelligence groups marked and progressive age changes are seen in the composition of the sample in each decade (Table 1)

Miles has pointed out that, although the decline corresponds to a change in Otis I Q from 114 in the twenties to 102 in the fifties, the effects of this drop may be masked by other factors at the higher per centile levels A great deal depends on the initial level Although a person in the top decile for adults may regress to a median position in the seventies, "individuals hav

TABLE 1
PERCENTAGE OF ADULTS BOTH SEXES AT EACH AGE DECADE IN SEVEN BRIGHTNESS CLASSES
(City B 567 Cases)

Class	20 s	30 s	40 s	50 s	60 s	70 s	80 s
A	42 3	28 9	35 6	12 0	10 8		
B	37 2	31 1	8 9	21 4	14 7	16 9	
C+	14 1	25 6	31 1	30 8	25 5	19 7	16 7
C	6 4	10 0	14 4	23 1	21 6	28 2	27 8
C–		2 2	8 9	6 9	14 7	12 7	5 5
D				3 4	5 0	8 5	11 1
F		2 2	1 1	2 6	6 9	14 1	38 9
Total	100 0	100 0	100 0	100 2	100 1	100 1	100 0
No cases	78	90	90	117	102	71	18

ing at this later period in life an intelligence scoring ability that is average or above for active adults and combined with it a great wealth of experience, easily maintain their eminence and leadership in the affairs of men and may successfully continue their business and professional activities to very advanced age Such people are honored and revered, and exemplify human life at its acme of effectiveness and fulfillment" (Miles and Miles, 1932, p 73)

To this we might add a consideration based on Lewin's concept of the 'circular causal relation" Persons of superior ability not merely enjoy the advantage of greater power and speed in learning but may also acquire better *ways* of learning Where superior work habits have been developed, these may be retained to a considerable extent even after the initial abilities are reduced

Less fortunate, in Miles's view, are those whose initial abilities are average for adults and who may fall to below the tenth percentile in late maturity As will be seen later, a number of studies have given evidence for an even more rapid rate of decline at lower than at higher intelligence levels The Stanford research however, offers no support for such a finding

II Studies Based on the Wechsler Scales

WECHSLER BELLEVUE AND WECHSLER ADULT INTELLIGENCE SCALE

In the standardization of the Wechsler Bellevue Intelligence Scales (Wechsler, 1944), a stratified sample was used based on the occupational distribution of the United States census This attempt to obtain a representative sample may have been successful so far as the test area was concerned (in and around New York City) Figure 5 presents results from 1751 cases in this standardization, in terms of verbal and performance scales (on the basis of the mean and standard deviation for the age group 20–25 years)

In the more recent Wechsler Adult Intelligence Scale standardization (1955), made 15 years later in connection with a survey in Kansas City, the drop in test score begins at a later age than on the Wechsler Bellevue and is less marked Anastasi (1956) has pointed out that the educational decline with age (fewer years of schooling among the older subjects) also is less marked in the WAIS sample and begins later This might be predicted if the score differences are regarded as produced

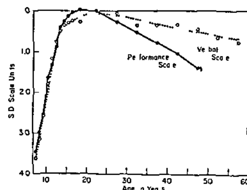


FIG 5 —Age means in the Wechsler Bellevue, in terms of the mean and standard deviation for ages 20–25

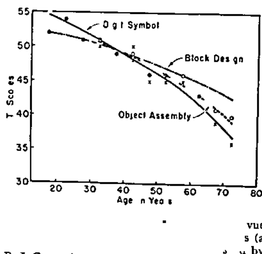
by educational trends rather than by the effect of aging However, the composition of the age differences in different subtests, indicates that other factors are also involved

THE SAN QUENTIN STUDY

In a criticism of the Wechsler-Bellevue standardization, Corsini and Fassett (1953) have advanced the novel hypothesis that the only way to obtain a representative sample of older persons is in prison Since a number of studies have indicated that the prison population is equal to that of the population generally, it is proposed that a "forced sample" of tests can overcome the difficulties of eliciting co-operation at the upper ages

These writers present the hypothesis that

ıntellıgence does *not* declıne sıgnıficantly from early to late maturıty and that the declıne noted by other ınvestıgators ıs maınly a functıon of poor samples and of the loadıng of non ıntellectual factors ın the tests The San Quentın sample drawn from an orıgınal pool of over 4000 cases, con sısted of the first 100 cases ın each 5 year age group from 15 to 60 wıth somewhat fewer cases beyond 60



vue
s (a
by
R J Corsını)

Fıgure 6 shows trends sımılar to those ın the Wechsler data wıth an average de clıne of more than 0 5 S D to age 50 and approxımately 1 0 S D to age 60 Marked declıne was also found for the pıcture ar rangement and pıcture-completıon tests

In Fıgure 7, however, some dıfferences can be noted as compared wıth the Wechsler Bellevue standardızatıon For comprehensıon and sımılarıtıes the dıffer ences are probably not sıgnıficant (slıghtly slower rate of declıne) For the ınformatıon test, the San Quentın data show a rıse rather than a slow decrement These find ıngs can probably be explaıned ın terms of samplıng shıfts ın the prıson populatıon ın relatıon to age dıfferences ın the basıs of commıtment and ın related socıal ed ucatıonal factors

Corsını and Fassett (1953), however, conclude that general ıntellıgence does maıntaın ıts level from early to late maturıty and that both the rıse shown by the ınformatıon test and the losses shown by the performance tests are ınvalıd The subtests whıch most closely fit theır assumptıons are comprehensıon, sımılarıtıes and dıgıt span, and they belıeve that these are the only ones ın the W B Scale whıch should be used for between age research Nevertheless, the San Quentın results are ın the maın so sımılar to those of other studıes that they seem to provıde lıttle basıs for a revısed ınterpretatıon

HAMBURG WECHSLER

A German revısıon of the Wechsler Bellevue (1956) has been used ın a test program coverıng the age range from 10 to 60 years Results for subtests can be compared wıth the data of the Wechsler Bellevue standardızatıon Although the comparatıve curves presented by Rıegel (1958) show sımılar trends ın the majorıty of the subtests the German averages rıse more slowly ın adolescence, reach a later

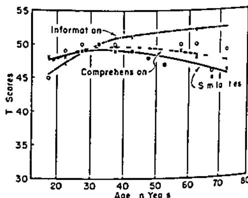


FIG 7—Age means for three Wechsler Bellevue subtests ın terms of T scores for young adults (a prıson sample)

peak, and (except ın the case of ınforma tıon, comprehensıon, and sımılarıtıes) de clıne somewhat more slowly after age 30 These dıfferences are sufficıently ınterestıng to deserve careful study of educatıonal and other samplıng factors whıch may be ınvolved

Reports have also been made on an Italıan revısıon (Malecı and Montanarı

1953, Maleci and Pessina, 1954) comparing subjects in the early twenties and in the fifties The results in general conform with other experience, showing a greater decline of performance tests than of verbal tests and, as a consequence, a significant deterioration coefficent for the older group

III Three Longitudinal Studies

THE IOWA STUDY (OWENS)

In a monograph and several ensuing articles, Owens (1953) has made an exceptionally thorough analysis of results from a 1950 retest of 127 Iowa State College freshmen tested initially in 1919 The test used was the Army Alpha Table 2 shows the gains from the earlier to the later testing expressed in terms of the standard deviation of a large norm distribution of State College freshmen

Four of the subtests showed negligible gain or loss Four showed gains significant at the 01 level and total scores registered a gain of 0 55 S D This is especially striking when one considers that for the same test and over the same age period a *loss* of approximately this amount was reported by Jones and Conrad

Several explanations can be offered for the difference in findings

1 As in other studies the differences are related to differences in ability levels At age 19 only 25 per cent of the New England group reach or exceed the median of the Iowa group
2 The Iowa group is educationally superior as well as superior in initial level Owens has shown that within his group gains in total score are related to amount of education
3 Sampling factors Of 363 freshmen originally tested 162 were unlocated or deceased Of 201 who were located 63 failed to co operate Owens found as would be expected that those co operating represent a slightly superior sample In view of a zero correlation between initial score and gain within his test group Owens regards the sampling bias as unimportant But it is impossible to know to what extent biasing factors correlated with later mental ability patterns may operate in connection with those members of the original group who have dropped out of sight The alumni who have done well are those who are most likely to answer a roll call
4 It may be noted that a large part of the gain in total score is contributed by the information and vocabulary tests abilities in which continued adult acquisitions may be expected especially among college graduates
5 A large part of the recorded total gain may have occurred in the first 2 or 3 years after the initial test Evidence for this is provided by the fact that the subjects who were younger in the initial test gained more in the retest undoubtedly this is because they had a larger part of their adolescent growth period left after the initial testing

TABLE 2

Gains in a Retest after 31 Years

Test	Gain	*t*
Following directions	04	
Arithmetical problems	− 10	
Number series completion	00	
Analogies	14	
Practical judgment	54	8 22
Synonym antonym (vocabulary)	55	8 26
Disarranged sentences	63	7 29
Information	93	17 44
Total score	55	11 17

Owens reviewed several studies of college students in which gains of from 0 4 to 0 9 S D have been found from the freshman to the senior year It seems very probable that, in the four subtests which showed little or no increment between 1919 and 1950, significant gains would have been found if these subjects could have been retested as college seniors Significant losses are therefore implied, in these subtests, following the college years

THE OAKLAND GROWTH STUDY

Similar to the Owens study is one by Jones (1958) covering a shorter period in early adult life Eighty three members of

the Oakland Growth Study were tested with the Terman Group Test repeatedly during the adolescent period and again at around the age of 33 A high degree of consistency was shown between the last adolescent testing and the first adult testing 16 years later, the retest correlation was 84 for the men and 90 for the women

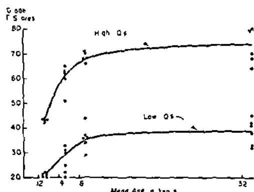


Fig 8—Average growth curves for groups at contrasting I Q extremes of a normal sample in terms of Grade XI T scores

Over a 20 year interval going back to age 12–13, the retest correlations fall to 78 for the women and 62 for the men We may infer that differential growth patterns in adolescence disturb the prediction of adult scores from earlier tests but that, subsequent to adolescence, little change occurs in relative position

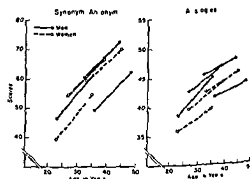
Figure 8 shows average curves for the highest and lowest I Q 's in this group (15 per cent at each extreme) The units are T scores based on the 16 year distributions The apparent slight divergence of the curves is due entirely to the more rapid growth of the higher I Q 's in the middle part of adolescence At later ages gains are similar but this may be an artifact due to limitations by the test ceiling on brighter individuals

For the group as a whole, the gain over a 16 year period amounts to approximately 1 year in mental age months From test norms it may be estimated that about half of this growth occurred before the age of 20 as in the Owens study, the subtests chiefly responsible were vocabulary and information Only 10 per cent of the increment could be attributed to tests concerned directly with the efficiency of mental operations (quantitative thinking and computing, analogical reasoning, and classifying)

It is of interest that, in a sample highly experienced in taking tests, age changes in early adult life reveal differential patterns so similar to those exhibited in middle and later maturity Unlike Owens' finding, there was no correlation between gains and years of education after high school

THE STANFORD GIFTED STUDY

Our most important source of evidence on adult abilities at the upper extreme of the distribution is to be found in the follow ups of the Stanford Study of the Gifted The members of this group, born between 1903 and 1920, were selected as having Stanford Binet I Q 's of 140 or above or as being within the top 1 per cent for their age norms on the Terman Group Test The Concept Mastery Test was devised for use with this group and examines



the subject's knowledge of concepts in many different fields through an analogies test and a synonym antonym test The test was given in two equivalent score forms in 1939–40 and 12 years later Figure 9 shows the mean 12 year gain in each of four age groups All gains are significant, amounting to about 0 5 S D for synonym antonyms and slightly less for analogies

Although other studies of tests requiring analogical reasoning have shown a decrement in this age range, a group as exceptional as this might be expected to have a delayed decline Moreover, many of the items in this analogies test reflect factual knowledge or phrase habits rather than reasoning or problem solving This is illustrated for example, in such items as the following

Fore Aft Bow (*a* Deck *b* Boat *c* Stern)

Nature Nurture Heredity (*a* Ancestry *b* Environment, *c* Health)

The nature of an item may vary according to a person's intelligence level The same item which demands analogical reasoning from one subject may be handled by another subject merely in terms of stock piled information We might evaluate this in terms of "knowledge thresholds An analogies task which is close to a person s knowledge threshold involves alternatives which at first seem almost equally reasonable and these alternatives must be checked and compared But if the task is so far above the threshold that it involves a person s everyday repertory of frequently rehearsed knowledge the solution depends more on simple word recognition than on reasoning From this point of view the Concept Mastery Test is well adapted to testing vocabulary and factual knowledge but is inadequate for the measurement of abstract thinking or ingenuity in problem solving among highly intelligent and well informed subjects

IV A Survey of Other Research

Although space is lacking to summarize all the age-comparison research which is relevant to this chapter a few examples will be given which illustrate the wide range of sources from which evidence is available

English Industrial Workers

The Progressive Matrices Test (Raven 1948) is a non verbal test which requires logical reasoning by analogy It has been reported as correlating 86 with the Stanford Binet and as having a *g* saturation of 82 A test of this nature, designed as an index of a person's "present capacity for intellectual activity independently of the language he speaks or of the knowledge he has acquired,' would be expected to show an early peak and a sharp decline with age Figure 10 presents age curves for this test, drawn for different percentile levels, the adult data are chiefly from tests of photographic employees and engineers The early segments of these curves suggest a doubt as to the homogeneity of the adolescent and adult populations A peak is reached at age 13–14—much earlier than in most normative studies of intellectual functions—and the flatness of the curves between ages 12 and 22 appears atypical To conform to other experience, one is tempted to extrapolate the rising limb of these curves to a higher peak at 17–18

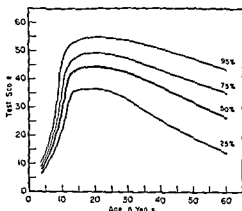


Fig 10 —Age curves (Progressive Matrices) for different percentile levels (After Raven 1948)

French Railway Operatives

A number of mental tasks were included in a battery of tests given to approximately 4000 French railway operatives (ages 20–55) and to apprentices (ages 12½–15½) In a report by Pacaud (1955), speed in a test of concentrated attention reached its peak in the early twenties Accuracy in

this test, yielded scores which provide a sharp separation of older subjects and those in the teens and twenties In a reasoning test median scores reach an early peak and show a fairly steady decline with age from the teens on However, the 90th percentile subjects reach their highest point in the early twenties

These results are sufficiently similar to other principal studies so that special comment does not seem necessary It may be presumed that an industry wide test program of this nature can maintain a better sampling at various ages than a cross sectional study based on volunteers It is not known however, to what extent selective factors may operate among those who enter or leave the industry at the upper ages

JAPANESE FACTORY WORKERS

In a Japanese study based on more than 25 000 cases, Kirihara (1934) has assembled data from a number of test programs administered before and after the war The subjects were for the most part factory workers in large industry and their families. Figure 11 presents the average and standard deviation by age, taking the age group 20–24 as 100 Kirihara states that "the progression of the raw score, on the average, showed a roughly linear increase from age 6 to age 13 or 14, then slowly increased up to about age 18, and gradually decreased after about 19" In the units employed, he states that the ratio of the speed of progression between 6 and 15 and the speed of retrogression from 20 to 70 was 100 16

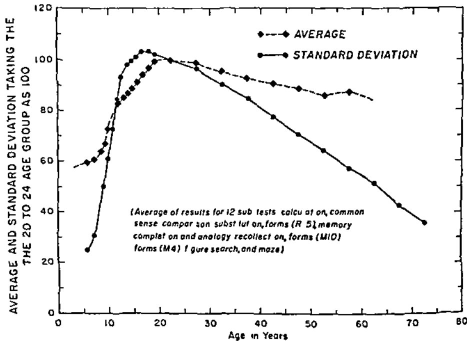


FIG 11 —Age changes in means and standard deviation referred to ages 20–24 as 100 (After Kirihara, 1934)

The amount of decline in this sample is somewhat less than is ordinarily reported, in view of the fact that the battery does not appear to include vocabulary However, the rapid decrease in standard deviation may imply a selected group in the later years Selective mortality may be a factor of some importance in this sample

One peculiarity of these data is a marked and consistent sex difference, found even in samples in which the men and women are

of the same environment as for example married couples Figure 12 illustrates this for four series of tests given between 1938 and 1941 Some tendency toward divergence in the curves may be noted after age 20 In these particular tests the means reached at age 60 correspond to the norms for early adolescence or even pre adolescence

American data on sex differences have presented nothing to correspond with the Kirihara findings Where differences occur they usually favor women rather than men especially on verbal tests Conrad *et al* (1933) for example reported significantly higher scores among females in all the tests of the Army Alpha except arithmetic number completions and information There was some tendency for these differences to increase after age 40

The results reported by Kirihara based on a large and carefully described sample suggest many problems for cross cultural inquiry It is doubtful however if existing studies are sufficiently comparable to serve as more than a basis for hypothesis

AIRCREW OFFICERS

In a study of an exceptionally homogeneous and highly trained group Glanzer and Glaser (1959) have reported on tests given to 454 aircrew officers of the Air National Guard and to 90 commercial air

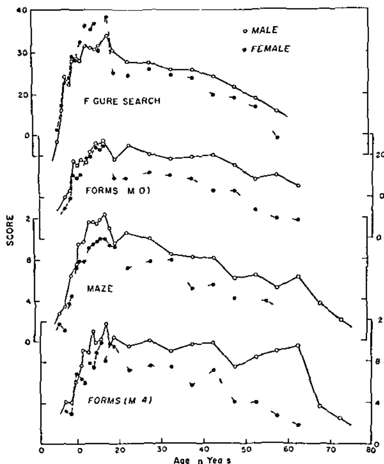


FIG 12 —Age curves for males and females in four tests (After Kirihara 1934)

line pilots Tests were selected because of the relevance to critical elements of the job and of their estimated value in predicting pilot skills In addition, they were chosen as 'age sensitive" on the basis of previous evidence from similar tests

Cross sectional data were obtained in an age range of 20–50 years and longitudinal data from retests at around age 33 of subjects who had been tested 12 years earlier on various tests the size of the longitudinal sample ranged from 34 to 179 (Table 3)

Although these tests involved components of a kind often used in intelligence tests, the interpretation of the gains found must take into account the fact that in their specific form they were designed to be job related The initial tests occurred when the subjects were new to their job the retests, after long continued training on similar functions This was, moreover, a high level group of "survivors" who were able to profit from this training

TABLE 3

COMPARISON OF CROSS SECTIONAL AND LONGITUDINAL DATA

	Cross sectional Data		Longitudinal Data	
	r w th C A	p	Ga n*	p
Interpreting data from technical instruments	− 33	001	1 4	001
Visualizing and interpreting mechanical principles	− 12	01	8	001
Numerical operations	08		6	001
Spatial orientation	− 14	01	6	001

* In terms of S D of init al test Although selected as be ng l kely to show an age decline all four tests exh b t h ghly s gnificant gains

It is rather likely that even a test such as Progressive Matrices or digit symbol substitution, would show improvement rather than decline in a selected group of individuals who had daily practice in related operations and whose jobs and perhaps their lives depended on the effectiveness of this practice Over a wider range to age 50, the cross sectional data show that, even under these relatively maximal training conditions, negative correlations with age occurred in eight out of fourteen tests (code learning, finding relationships, identifying marginally visible objects, orientation to new equipment, etc) The exceptions were chiefly tests of reading and mathematical skills

V Differentials in Growth and Decline

Peak of Growth as Related to Decline

The increasing deficiency of older persons in such tests as analogies has led to the question of whether this may be psychometric rather than an actual defect in analogical reasoning A test may yield spuriously low average scores if the instructions or other conditions of the task are inappropriate for members of the group On the basis of results from 70 hospital cases, ages 20–59 Weisenberg *et al* (1936) concluded that test adaptation was not an important factor in analogies and that it was more probable that the peak performance in this aspect of mental functioning actually occurs in early maturity This is in conformity with the conclusions of Jones and Conrad and of Willoughby

What implications can be drawn from the fact that on some functions an early peak seems to imply an early decline? One possibility might be that the function is closely related to school learning, that schooling promotes rapid growth, and that absence from school leads to an almost immediate onset of decline

In Willoughby's research as already noted, the earliest peak (age 17) is reached by symbol series completion, followed by verbal analogies, number series completion, and digit symbol substitution (age 18) All these were marked by a drastic decline in adult life In this urban sample the per formance dropped to a pubertal or pre pubertal level by the age of 60

These tasks involve learning problem solving, and discrimination in the use of symbols but show no direct relation to the content of classroom learning Closer to the classroom are vocabulary, science nature in formation, and arithmetic reasoning all of which attain peaks later than age 20 and exhibit relatively little decline Similarly in the Jones Conrad study an early peak is reached in the analogies and number com pletions tests, with an exceptionally rapid decline, a late peak in opposites (vocabu lary) and general information with little decline to age 60 Arithmetic showed only a moderate downward trend

Another interpretation of the early peak–early decline functions is that of all the tests, they are the most sensitive to matura tion during the growth period and to decre ments in neural efficiency during mature life They may be thought of as represent ing the "fluid abilities' of Cattell (1943) or the "basic" mental abilities of some other writers They would be accounted for chiefly in terms of genetic predisposition Traits which mature late and hold up well in maturity are more likely to be the "crystallized abilities' of Cattell and to have a strong component of experience and environmental support Some of these con siderations will be explored in a later sec tion in a comparison of analogies and other tests with regard to the speed factor

Subtest comparisons for the Wechsler-Bellevue yield similar implications Fox and Birren (1949), Madonick and Solomon (1947), and Rabin (1944) have shown relatively poor performance among the eld erly in the case of digit symbol substitu tion, picture arrangement, and block de sign In the Wechsler standardization these all reach a peak at age 20 or earlier

ABILITY LEVEL AND AGE CHANGES

The question has often been raised as to whether age changes are related to ability level Variability changes with age are rele vant to this problem An increase in varia bility would imply divergence of curves, with relatively slow rates of decline among those at higher ability levels Reduced variability, unless of psychometric origin, as in the case of too low a test ceiling, would imply a tendency for curves to con verge and for the bright and dull to become more similar with age

Another approach to the problem is through the comparison of different occupa tional or educational groups Vernon (1947–48) has noted that decline in the Progres sive Matrices test varies according to oc cupation and is greatest at the lower oc cupational levels, very high scores hold relatively constant up to 25 or 30 years This is based on a sample of about 90,000 candidates for the Royal Navy The Mat rices test is described by Vernon as "one of the purest tests of *g* available, hence it should not be affected by education or by the exercise in manipulating verbal and numerical symbols which, say, clerks and electricians get" (Vernon, 1947–48, p 61) In finding that the amount of age decline is related to low occupational level, he considered that this might be determined in part by occupational differences in test adaptation or test sophistication Vernon's findings appear to be in general agreement with those of Raven, who reported a greater rate of decline in the lower percentiles (see Fig 10)

What explanation can be assigned for this? A functional theory would emphasize the effects of use and disuse Persons with poor levels of mental ability enjoy and practice mental functions less than those who are already proficient Thus (like the athlete and the inactive person) they draw further apart in their abilities But it may

also be hypothesized that the interaction of mental functions accounts for the maintenance of these functions This conception could be developed to explain not merely the differentiation of age curves but also the accelerated decline which may occur at relatively high levels of ability in later decades

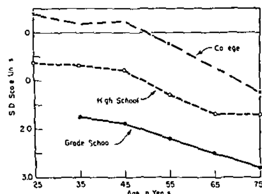


FIG 13 —Age means for three educational groups in terms of standard deviation scale units

Gilbert (1941) reports an occupational differential for the tests she has used in determining efficiency indexes and this is also seen in the work of Sorenson (1933 1938), who emphasizes the sustaining effect of the more intellectual occupations upon intelligence scores Some investigators, however have failed to confirm this relationship In the extensive study by Pacaud (1955) of French railway workers, elsewhere referred to score differences of different educational groups either remained about the same or tended to decrease with age This somewhat unexpected result is difficult to interpret without further information about the sample It is possible that the higher educational groups may be socially more mobile and more likely to be recruited into other occupations

The Stanford Maturity Study (described above) is one of the few in which rates of decline appear to be identical for different educational groups This is shown in Figure 13, comparing persons with 8 years 12 years, and more than 12 years of education It is possible that the techniques of this study obtained a more homogeneous selection at the higher than at the lower educational levels If less able subjects, who are more numerous at the lower levels, are especially difficult to recruit in the later years, this would tend to produce parallel rather than divergent curves

VOCABULARY AND DIFFERENTIAL DECLINE

In the foregoing sections frequent reference has been made to differential decline and to the tendency of vocabulary tests to maintain their level much better than most other types of tests used in intelligence scales (except, perhaps, information tests)

Various studies are not, however, in complete agreement This can probably be attributed to differences in selection Where a sample is large enough to be analyzed for different ability levels, results such as those in Figure 14 are to be expected This figure is based on an English survey represented in an earlier chart in connection

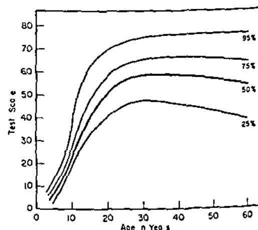


FIG 14 —Age curves (vocabulary) for different percentile levels (After Raven 1948)

with sharply declining performance in a different function (matrices [see Fig 10]) Data for over 5000 cases, apparently including this sample, are also given by Foulds (1949)

The vocabulary curves analyzed by Foulds and Raven (1948) are marked by a peak at about age 25 for the lower half of the distribution, a somewhat later peak

in the top percentiles, increasing dispersion with age, a vocabulary decline which is quite marked in the lowest 25 per cent, and a plateau or slightly rising level for those at the 95th percentile or above In the higher brackets this may be taken as evidence either for constancy of information and vocabulary or for a balance in which "the amount of general information acquired is about equal to that forgotten" (Foulds, 1949, p 241)

A nation wide sampling of the United States by Thorndike and Gallup (1944) has been noted earlier in another connection. In this study a carefully drawn sample of the voting population of this country was given an untimed test based on all ten levels of vocabulary CAVD (Columbia Arithmetic, Vocabulary, and Directions) Table 4 shows a slight decline in medians and a slight broadening of the interquartile range from age 25 to "over 60" The "over 60" median corresponds to an Otis mental age of slightly below 16 years

TABLE 4

VOCABULARY (FROM CAVD) IN DIFFERENT AGE GROUPS

Age	Q_1	Median	Q_3
21–29	8 18	11 34	14 33
30–39	8 15	11 31	14 21
40–49	7 64	11 24	14 03
50–59	7 72	10 90	13 98
Over 60	6 70	10 28	13 52

The authors point out that although there is little decline in age in "verbal power," the decline might be as much as 30 per cent greater if selective factors in the upper ages could have been controlled But the difference in score between the younger and older subjects would still amount to only about 1 year in mental age This is probably the best source available as to age changes which may be expected in a verbal test given without time conditions and consisting of 'basic and familiar material" rather than of *novel or problem solving tasks*

The difference between age changes in vocabulary and in a problem solving task (Knox Cubes) is graphically shown in Figure 15, from a study involving a farming population in the East and Middle West

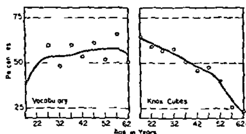


FIG 15 —Contrasting age curves for vocabulary and a performance test (Adapted from Heston and Cannell 1941)

This pattern of age differences occurs at all levels of mental ability In a study of 456 feeble minded, Jones (1932) compared children and adults of substantially the same Stanford Binet mental ages The mental age scores, however, were obtained in quite different ways by members of the two groups

> In general it is apparent that the markedly easy tests for adults are those which are more readily subject to casual training definitions, verbal understanding and such tests as naming coins and counting pennies Tests particularly difficult for adults are those which present the most novel situations or which require ingenuity or persistent effort Tests of memory span markedl handicap the adults, it is possible that
> into
> Bey
> adults
> guage [Jones 1932, p 49]

A corollary of the foregoing is that the children, although mentally deficient, still have a potential for mental growth, while the adults are dependent on what they can retain from the accumulations of previous years

THE USE OF VOCABULARY IN APPRAISING DETERIORATION

Within a group of a given age, vocabulary *has often been shown to be strongly* related to "total intelligence " Over a wide age range however vocabulary scores have much poorer validity because they are relatively insensitive to age changes which adversely affect other aspects of mental ability A practical application of this is to use current vocabulary to indicate the peak level of a subject's earlier intellectual development and to provide a reference point against which degree of deterioration can be assessed

TABLE 5*

PERCENTAGE DEFICIT ON DIFFERENT EFFICIENCY TESTS

Test	Per Cent Deficit
General information	12
Repetition of sentences	18
Memory of paragraph	24
Counting 20 to 1	32
Sentence completion	33
Analogies	40
Substitution	42
Number completion	46
Retention of paired associates	56

* After Gilbert (1935)

The Babcock Test of Mental Efficiency (Babcock, 1930 1941, Babcock and Levy, *1940*), originally designed for the measurement of mental deterioration in psychotics, involves the assumption that deterioration occurs first in new learning and in the formation of new associations Using the Terman Vocabulary Test to indicate the original adult intellectual level, and a variety of mental tasks to register the efficiency *phase of intelligence*, the discrepancy between the two is taken as an index of deteriorative change Gilbert (1941) has listed the "per cent deficit" found on different efficiency tests Although the use of percentage computations may be open to question, Table 5 provides a rough indication of the relative size of the discrepancy which develops *in the sixties between these* functions and vocabulary The table includes illustrative items from a comparison of 175 individuals, aged 60–69, with 185 persons between the ages of 20 and 29

Although this method may be useful in giving a clinical estimate of deteriorative *changes, certain limitations may be noted* The assumption of a constant vocabulary level in the adult years may be generally correct but has many individual exceptions *For those who show a decline in vocabulary* beyond the age of 60, as noted by Shakow and Goldman (1938), the Babcock method may underestimate general mental deterioration *On the other hand, it may over* estimate it for persons at higher general intelligence levels who continue to grow in vocabulary

Moreover, some allowance must be made for specificity in mental functions and for different profiles of abilities in different persons At the peak of growth the intercorrelation of vocabulary and *other mental* abilities is not likely to be greater than 70 This accounts for only about half of the variance of the efficiency tests and is compatible with wide discrepancies in the levels of different functions

Among children the prediction of future mental development is handicapped by idiosyncratic variations *in growth rates* which occur in many children The diagnosis of deterioration is perhaps even more handicapped, in view of the multiplicity of factors which are operating and the long period of time over which they have had effect Wherever possible (as for example, in personnel records) the best approach *to this problem is through cumulative* measures rather than through inferences from tests administered on a single occasion

Two other factors need to be *considered*

ulary has been maintained Feifel (1949) and Yacorzynski (1941) have shown changes in the way words are defined, indicating that a loss of context may occur *without a corresponding change in vocabu*

lary scores Similarly, Fox (1950) has raised the question as to the comparability of deficits in different age groups, since subtests do not necessarily measure the same function throughout the life span, a low score on a given test may have a different significance at different ages Al though this psychometric problem affects our interpretation of the efficiency index as a quantitative value, the Babcock pro cedure may still provide a useful estimate for some clinical purposes

VI Methodological Issues

Longitudinal and Cross Sectional Methods in the Study of Aging

The discussion in this section is based in part on a conference report by H E Jones (1950) Although the primary in terest in old age research tends to be focused upon age changes, our scientific evidence consists chiefly of data for dif ferent individuals in different age groups Such records yield normative indications of age decline, but they tell us little about process or about dynamically associated factors Moreover when we do not observe age changes directly but merely infer them from comparing samples at different ages, we must be constantly on guard against conditions which would vitiate our analysis —conditions which are especially likely to modify, in a progressive way, the sampling factors or the motivational factors in groups supposed to represent widely separated ages

One of the sources of error in cross sectional data lies in the fact that at different age levels somewhat different methods tend to apply in locating and motivating subjects This all too readily may lead to non comparable samples If we try to avoid the difficulty by matching for socioeconomic status at different age levels, we are likely to find that we are comparing subjects with different educational backgrounds, owing to secular trends in factors related to schooling By the same token, if we match for years of schooling, we cannot be sure that we have matched successfully for quality of schooling and, in any event, will probably discover that we have unbalanced our samples in other respects

Differential environment is hard to allow for in the case of age samples which have lived through different cultural periods, with different economic conditions, different schooling, and perhaps different standards of living, values, and symbols of suc cess Even when we are most scrupulous in attempting to control these disturbing variables, we may find that the effect of selective survival has not been controlled The differential birth rate, which has led to so many mistaken conclusions in studies of children, may at later ages have its counterpart in differential mortality, but here the problem becomes especially complex be cause as yet we know so little about the operation of this factor in relation to spe cific variables

Among children and adolescents we have learned that physical growth curves of in dividuals are surprisingly regular in their irregularities Where the perturbations of individual growth are not typical of age but typical rather of a phase of physiolog ical maturing, characteristics which are so common as to be almost universal may not even be suspected from the portrayal of averages

Beyond these common characteristics of growth, students of child development have been increasingly concerned with individual differences in the pattern of growth, for children vary not merely in measures of status at different ages but also in their courses of age change The existence of these pattern differences (as, for example, between the early maturing and late maturing adolescent) cannot readily be shown in cross sectional norms of development. Various masking effects of such norms are also to be anticipated at the other end of the age scale, where we should be especially interested in patterns Within a normal range it is rarely necessary to intervene in

cases of early or late maturing except to provide appropriate personal and social guidance But common instances of early senescence present us with precisely those kinds of variation that we are most concerned with studying from the point of view of prediction and possible control

Why should our investigators rely chiefly on a method which will not enable us to observe these patterns? The answer lies of course in the fact that cross sectional methods are quicker and less expensive Moreover longitudinal methods have their own special problems Some of these arise from the inevitable shrinkage of sample Cultural trends may introduce changes which are difficult to distinguish from age changes Data collection programs may be saddled with obsolete methods which cannot be rejected because of the necessity of maintaining comparable records In spite of these and other hazards the fact remains that if we wish to study individual patterns of age changes and individual differences in these patterns there is no substitute for cumulative and long continued observation of the same life span sample

MOTIVATION

At ages before school entrance the performance of children on mental tests is not easily motivated on the basis of an interest in test performance or intellectual activity as such Personal factors in the situation or peripheral aspects such as attractive test materials may need to be especially cultivated as incentives

Old age may involve a return toward this motivational level except perhaps in the case of subjects who are intellectually active and have maintained an interest in mental performance for its own sake Especially beyond the age of 60 it is reasonable to suppose that motivational losses may account in part for the decline in mental ability scores The slower decline sometimes noted at the upper end of the intelligence distribution may be related to a slower rate of change in motivation

But there are limits to the improvement of test performance through restimulated motivation To the extent that loss of intellectual interest is generalized a lagging test performance may be a valid rather than an invalid indicator of actual abilities Even if we can succeed in altering the motivational pattern in a person who has lost interest in intellectual activities we may not be able to reverse the changes which have occurred in his mental functioning (For an illuminating discussion of motivation in problem solving see Kay *1955 pp 265 ff*)

The general problem of motivation in old age research is ably discussed by Kuhlen (1950) We sometimes speak of motivation as though it were a prime mover which could be turned on or off irrespective of target mechanisms But motivation and ability are usually interactive We like to do things that we can do well We become resistant toward activities which reveal our shortcomings

SENSORY FACTORS

In the testing of older persons it is necessary not to confuse sensory handicaps with decline in mental scores Group tests may undermeasure elderly persons who have visual difficulties not fully corrected by glasses or who do not hear well enough to be sure of the instructions Jones and Conrad (1928) examined these factors through comparing performance on tests which might be expected to be differentially influenced by visual or auditory handicaps No evidence could be found that the obtained age differences were related to such defects A comparison was also made between 911 group test cases with 280

cases probably due to the fact that these were supplementary cases not reached by

ordinary methods and needed to complete a village sampling At any rate it is clear that optimal conditions were not effective in canceling the age decline

Sensory deficits involve both qualitative and quantitative restrictions a loss of ability to receive necessary content and also a decrease in the excitation values of sensory input In testing elderly persons the audibility of instructions and legibility of test materials are always points of concern A discussion of precautions and procedures especially appropriate in the testing of older persons can be found in papers by Conrad (1930 1931) Conrad and Jones (1929) and Conrad *et al* (1933)

EDUCATIONAL FACTORS IN TEST PERFORMANCE

Educational differences have been suggested to account for the results of Tuddenham s (1948) study of enlisted men in World War II whose scores (measured by a test derived from the Army Alpha) were very significantly higher than in corresponding samples in World War I Assuming that this is not due to higher enlistment standards in the 1940 s it leads to the possibility that the age decline would be reversed if from different test programs we could compare younger persons born (let us say) in 1900 and tested in 1930 with older persons born in later years and tested in the 1960 s A more direct approach is through matching different age groups for educational status

The validity of our current standardized tests for the mental measurement of adults has been criticized on the ground that they are oriented toward school learning rather than toward life achievement However a study (Jones 1959) of a group of men in their middle thirties has shown as high correlations between high school tests and later estimates of vocational and economic success as are usually found between the same tests and school grades Figure 16 presents these correlations for the Stanford Achievement Test (administered in the ninth grade) and various adult measures based on ratings by an interviewer The 01 level of significance for the correlations falls at the right margin of the shaded area Although related to earlier mental ability, it should be noted that adult measures were uncorrelated with earlier family status (socioeconomic measures obtained during the adolescent period) In the study by Owens (1954) the correlations were computed between test gains after age 19 and income 30 years later The only test showing a significant correlation with income was analogical reasoning often cited as presenting a test handicap for older adults but also as being highly saturated with *g*

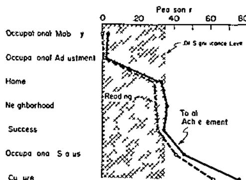


FIG 16—Correlation profile for ability scores in adolescence and measures of adult status

In the case of tests resting on verbal experience such as vocabulary, we might expect that for environmental reasons alone there would be differential age changes produced by education level This has been suggested by a number of writers and is also well brought out in Figure 14 from the study by Raven (1948) previously referred to This figure is based on the Mill Hill Vocabulary Scale The percentiles refer to ability levels but of course they also represent an educational differentiation

PSYCHOMETRIC PROBLEMS

It is much easier to devise a test for a single cultural group than one which pro

vides a valid comparison of widely different groups This applies also to age comparisons, since persons widely apart in age represent differing samplings of cultural exposure and assimilation Even where a test seems relatively culture free (such as an abstract symbol manipulation test), we cannot be sure that it taps the same functions at different ages

It has often been suggested that a different set of criteria should be utilized in constructing tests for older persons Kaplan (1954) has commented "Intelligence tests encompass only a limited range of mental abilities and either undervalue or ignore some of the abilities which are most important in daily life For example, they do not adequately provide for the measurement of originality and the higher forms of judgment" The practical applications of this might justify a parallel program of testing, but this should supplement rather than substitute for programs which appraise aging, from early to late adulthood so far as possible within a single frame of reference

The age comparisons that are made in this report appear for the most part to have a reasonable degree of validity, but their scientific adequacy is much less than could be desired Future research will construct age curves based on primary abilities which have been elicited from factor analyses made at a series of ages These abilities will have a significant place in the measurement of adolescents and of adults during the productive period of their lives

In 1955 Thurstone presented for the first time growth curves based on seven primary mental abilities These were derived through multiple factor analysis from test data for large groups of children and adolescents Unlike the crude descriptive curves of this chapter the primary ability curves have a defined zero point and equal units. Of the seven factors, drawn to age 19, the slowest to mature is word fluency (reaching only 70 per cent of the adult asymptote at that age), and the earliest to mature are perceptual speed, the visualizing space factor, and inductive and deductive reasoning, all of which pass the 90 per cent point at 18 or earlier

> The Perceptual Speed factor reaches 80 per cent of the adult performance at the age of 12 The Space and Reasoning factors attain the same relative performance at the age of 14 The Number and Memory factors reach this level at about 16 The Verbal Comprehension factor develops more slowly and it reaches the same relative level at the age of 18 The Word Fluency factor matures later than 20 It is not surprising to find the Perceptual Speed factor maturing rather early and the Verbal factors maturing quite late [Thurstone 1955, p 4]

Future research must extend these age curves for primary factors into adulthood and later maturity When this is done, most of the studies reported in this chapter will have little more than a historical interest, it may be hoped that in the next edition of this *Handbook* it will be possible to discuss adult mental abilities in more adequately quantitative terms and with scaled measures for specific functions

MENTAL ORGANIZATION AS A FUNCTION OF AGE

The small number of factorial studies that have been made to date yield somewhat inconsistent results as to age changes in the differentiation of mental abilities In one of the best known of these, Garrett (1946) found a decreasing intercorrelation among scores in different tests, from childhood through the college years This implies that mental growth is accompanied by increasing specialization and decreased saturation of test scores by a general factor

In a factor analysis of the Wechsler standardization data, Balinsky (1941) reported a decreasing intercorrelation of tests from age 9 to ages 25–29 But the *g* factor, relatively prominent at age 9, again became prominent in the fifties McHugh and Owens (1954) also report a tendency for the general factor to become more prominent in the middle or late adult years, the first or general factor accounted for 53 per

cent of the total variance at age 19 (*seven subtests of the Army Alpha*) *and 63 per* cent of the total variance at age 50 They accounted for this in terms of reduced en vironmental differences in the adult years as compared with the childhood and ado lescent years, but they suggest also that a maturational explanation would be possi ble The problem is a difficult one partly because of the necessity of controlling het erogeneity

Where a composite test is used based on a sampling theory of intelligence it is obvi ous that an age curve although based on the same items throughout will necessarily represent somewhat different things at dif ferent ages The test is only superficially the same, since its nature as a measuring

with age Jones has noted

It is not merely a question then of a rubber *yardstick but of fluctuating incommensurables* which are treated as though they were one vari able In view of the forego ng one can hardly

of a picture showing in terms of acceptable definitions of mental ability a peak in the late teens or early twenties and a subsequent de cline which on the average becomes of con siderable magnitude beyond 50 Few of us doubt that there are implications from such an age curve for personal adjustment *for intel* lectual production and for employment [*Jones* 1950 p 124]

The varying significance of items at dif ferent age levels has of course a parallel at different intelligence levels One possible expression of this has been noted by Doll who quite early recognized that the feeble minded tend to be the strongest in items involving experience and weakest in those presenting new kinds of tasks

It may be that defectives support *their lame* intelligence poor comprehension and lack of judgment with the crutch of memory and that some tests which are good tests of intelligence for normals are with defectives tests of accom plishment or show the results of mental substi tution much as the senses of touch and hearing with the blind take over to a considerable de *gree the function of vision* [*Doll 1919*]

TEST PRACTICE

Lack of familiarity with tests may be a factor in the performance of older persons who are remote from schooling and whose

TABLE 6*

MEAN PERCENTILE SCORES IN REASONING

	Session			
	1	2	3	4
Institutional aged	2 0	1 4	2 3	3 2
Community aged	5 4	8 2	11 0	11 7
High school	35 9	54 0	63 7	72 2

* After Kamin, 1957

*TABLE 7**

MEAN PERCENTILE SCORES IN WORD FLUENCY

	Session			
	1	2	3	4
Institutional aged	5 0	7 4	10 3	17 4
Community aged	16 1	26 3	29 9	45 6
High school	31 8	63 6	82 7	91 7

* After Kamin, 1957

experience may not at any time have in cluded procedures of the kind used in psy chological examinations A well planned experiment by Kamin (1957) included the use of the Thurstone Primary Abilities Battery in four sessions The subjects, all volunteers were paid for their services, they included 25 institutional aged, 25 mem bers of a senior citizens' club, and a high

the two primary abilities, Tables 6 and 7 show the results of the four sessions, in

terms of Thurstone s percentile norms Although significant gains occurred as a result of practice the three groups remain clearly differentiated Differences in practice or in familiarity with the tests cannot account for these age differences However the implication is strong that a group that has had special practice should not be compared with a less practiced group This should be kept in mind in connection with the interpretation of such studies as those by Bayley and Oden (1955) and by Glanzer and Glaser (1959) where the practice although of a less formal nature is a matter of almost daily experience

An incidental outcome of Kamin s experiment involves the order of test presentation—relevant to the problem of fatigue effects of a test situation The two groups of older subjects were given the five subtests of the battery in a Latin Square design variance analysis showed no effect of either order or sequence in presentation

THE SPEED FACTOR

In a timed mental test scores are obviously influenced by individual differences in speed or in the number of items which can be completed in a given time This is often thought of as a superficial aspect of mentality related to personal style rather than to actual ability Ways of life may affect a person s quickness or slowness in everyday activities and this may transfer to mental test operations

A younger person may live in a peer culture in which pep is at a premium Children in school are accustomed to tasks which are compressed within time limits with quick starting and stopping Older persons may be more impressed by the advantages of cautious deliberation Answering a mental test often involves a certain willingness to gamble and perhaps the elderly are less likely to take a chance either in driving a car or in seeking a solution to a problem Mental tests which reward marginal snap judgments and chance taking attitudes may favor younger subjects

Decreases in rate of perceptual and motor performance are summarized in other chapters in this volume It is known that age changes occur very early even beginning in adolescence in various rates of physiological recovery We should not be surprised to find early change in the speed of mental operations and because of this the suggestion has often been made that our tests of older persons should always be adapted to this factor

Experiments with Time Limits

We permit a 60 year old to wear his bifocals when he takes a mental test Why should we not adjust the test to his changed speed requirements as well? In an early study Miles (1934) reported on results with the Otis test given without time limits to 433 subjects as compared with the same test (in an alternate form) administered under standard time limits The decline from early maturity to the sixties was 0 46 S D unit without time limits and 0 76 S D unit under standard conditions Assuming comparability of samples one might concl de that about one third of the [illegible]

However in the sixties to the eighti[illegible] the investigator noted that this relationship reversed with a decline of 0 98 S D unit without time limits and of 0 87 in the standard control She proposed that in early and middle maturity speed declines on the average rather faster than power whereas in late maturity the decline of power is relatively more apparent (Miles 1934 p 209) The second part of this statement does not rest upon a statistically significant difference For these later years perhaps all that should be claimed is that the removal of time limits fails to retard the rate of decline

The effect of time requirements may vary according to the nature of the test This is illustrated in an experiment by Schaie *et al* (1953) who gave the Thurstone Primary Abilities Tests to 61 subjects

between the ages of 53 and 78 Under the usual time limits there was evidence of age decline in each test With time unrestricted, all scores were raised, but on the tests of reasoning and of the space factor the im provement was greater for the younger than for the older subjects On these tests and for this age range, we may conclude that the effect of standard time limits is to di minish, rather than to increase age gra dients

Gilbert (1935) has noted that, as a gen eral rule the age decline is reduced in tests which are not weighted for time "But the loss remains significant and is greatest in the type of test which requires the forma *tion of new associations least in tests close* to simple vocabulary '

Christian and Paterson (1936) give an interesting example of results from a vocab ulary test Scores were obtained from 200 University of Minnesota freshmen and also from 179 parents and relatives As shown in Table 8 the scores favored the younger subjects in a timed test comprising 120 items but this age difference was reversed when speed factors were reduced by count ing only the first half of the items

TABLE 8

MEAN SCORES IN RECOGNITION VOCABULARY

Age Group (Years)	120-Item Test	Items Attempted	60-Item Test
18	87 5	116 7	43 4
40–49	84 2	101 5	48 8
50–59	81 9	100 6	48 6
60–69	79 3	92 9	49 9

Another kind of comparison can be made in the case of psychomotor tests some of which are given with standard time limits and others without time restrictions This has been reported by Heston and Cannell (1941) for the Ferguson Form Boards as compared with the Porteus Mazes The lat ter are given without time limits Figure 17 shows very similar age curves in the two functions The sample consisted of 643 per sons, a farm population in Maine Ohio, and Missouri, who were clients of the Farm Security Administration

In connection with the Kansas City studies of aging, Wechsler analyzed the re sults for five tests of the Wechsler Adult *Intelligence Scale, given under both timed* and untimed conditions to subjects between 60 and 65 and 70 and 75 The average in crement in raw score when subjects were

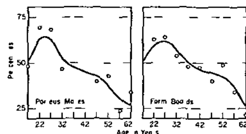


FIG 17 —Age curves for two tests differing as to time requirments

allowed unlimited time was actually very small and there were no significant effects upon age differences From the results on these and other age groups he concluded

Altogether our findings show that the older subjects were negligibly if at all pe nalized by a speed factor I believe that the same would hold for most other well standardized tests of intelligence (Wechs ler 1955*a* p 277)

A different approach to this problem has been made by Lorge (1936) in terms of *Thorndike s concepts of intelligence* Thorndike (1927) long ago pointed out that an individual s mental test score, in a time limit test is determined by the *level* of difficulty which he can reach in success fully answering items, the *range* or num ber of items which he can complete at a given level, and his speed In order to eval uate the influence of the speed factor in various studies reported in the literature, Lorge selected three groups of 23 persons each at age levels 20–25 27 5–37 5, and over 40 these groups were matched person to person by a highly reliable power test (CAVD, given without time limits) Table 9 shows the mean scores in these three groups, on a series of intelligence tests

The evidence for this is in Figure 20, which shows changes in the composition of test scores at successive ages for the Jones Conrad (1933) sample It can be seen that, beyond age 50 the vocabulary and the information tests contribute more than 40 per cent to test score whereas their contribution is less than 30 per cent in adolescence As noted elsewhere these tests are strongly influenced by environmental factors and the mere accumulation of experience They have value in the testing of persons at a given age level and within an appropriate educational range But in the comparison of age levels they especially favor older persons

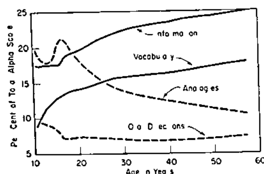


Fig 20—Age changes in the percentage contribution of different subtests to total Alpha score

It is clear from Figure 20 that a person who grows older may show increases in experience weighted subtests, together with decreases in subtests that reflect intellectual ability more directly In this way he may maintain the same total score achieved at an earlier age Unless test composition is taken into account such results may lead to interpretations of doubtful value

Speed and Power in Various Tasks

Speed differences occur between younger and older subjects in many kinds of tasks Korchin and Basowitz (1956) have found this, for example in the reaction to ambiguous pictures The difference is shown in vacillation as well as in delays in making decisions The difficulty of the older subjects in clarifying the phenomenal field and in maintaining judgmental frames of reference is interpreted by the writers as a function of ego organization and as being especially affected by anxiety and by organic deterioration "In these conditions of lessened strength, individuals cannot as well distinguish important from irrelevant aspects of the task and their behavior in novel or stressful situations tends toward rigidification and/or confusion" (Korchin and Basowitz, 1956, p 93)

A point to bear in mind in the interpretation of all such phenomena is Birren s comment on the evidence not merely for slower input and output mechanisms but also for increased latency in ' the linkage between perception and appropriate behavior (Birren 1955*b*, p 104)

In general it can be said that as tasks become more complicated, they become more sensitive to age In a group of semi skilled workers, Brown and Ghiselli (1949) found that operations involving simple arithmetic were maintained very well through the forties But when a compound process was required, such as both addition and subtraction within a single item, a decline in efficiency was noted after the twenties This is similar to Clay's (1954) finding that as the complexity of a task increased older persons became less accurate and less effective in correcting errors Rigidity in mental set, as shown in Heglin s (1957) problem solving experiments, is also an age differentiating factor Tasks which require a change of procedure or a substitution of new rules are particularly difficult at the later ages

A three dimensional representation is needed to show the relation between age, performance, and difficulty A good example is provided by Kay's (1955) analysis of results from a problem solving experiment in which subjects were presented with a row of light switches and a row of lights Any switch could be connected by the experimenter with any light With changes in the coding of spatial relationships the task could be increased in complexity Figure 21

shows a rise in errors with age associated with different levels of difficulty Kay found that the results for the more difficult levels were partly determined by interfering factors from earlier procedures and by less flexibility in the adaptation of the older subjects

Speed and Accuracy

On simple tasks in which the subject can choose his own tempo older persons are sometimes reported as slower but more accurate than yonger subjects (Welford 1950) This more painstaking approach suggests a different choice of goals in line with different aptitudes The implication is favorable with regard to the functioning of older persons in many types of operations in industry

The relation between speed and accuracy varies greatly accord ng to the task and the difficulty level Birren *et al* (1954) found that in doing arithmetic problems the age decline in accuracy is more rapid on the longer problems But as shown in F gure 22 the rate differences between younger and older persons are greatest on the problems which involve the fewest operations per second Because of a generally slower tempo Birren (1954 p 159) infers that in longer problems the elderly have greater time to dissipate any residual effects from previous operations

In another investigation by Birren (1955*a*) 341 subjects between 16 and 90 years of age were given the task of writing (for 2 minutes each) words beginning with certain letters The older subjects listed fewer words for all letters but were relatively poorer on the easy letters such as *S* where there are many words to choose from This could not be accounted for by differences in writing speeds but evidently involves a fluency factor similar to that in the Stanford Binet association test

VII Age Changes in Creativity

Another approach to the study of age changes in mental functions is that of Lehman whose numerous publications are summarized in a 1953 volume, *Age and Achievement* Lehman s procedure has involved the selection of objective evidence of achievement made by appropriate authorities without reference to the age of the achiever (e g scientific publications and works of art) These are then classified according to the age when produced and the average production is computed per age interval

As an example Lehman made an age classification for nearly a thousand contributions sufficiently noteworthy to be mentioned in a history of chemistry The highest proportion of these occurred when the contributors were in the age interval 30–34 Two-thirds of these contributions were made before 40 and only 3 per cent after age 60 For contributions of the highest merit (52 of the greatest discoveries as judged by three chemists) the modal age interval moved back to 25 29 Of the 52 contributions 32 were made before 40 and none after 60

These results are compatible with an early rather than a late peak of intellectual ability and with a subsequent decline rather than a plateau The peak of scientific or artistic achievement would be expected somewhat later than the peak of intellectual growth After this growth is reached time is usually required to attain the necessary experience and opportunity for high achievement The fact that so little time is needed especially for the highest quality of creative work offers implications as to the component of native ability in such work although it is obvious that many factors of motivation and opportunity must also be present

Results for other scientific fields for paintings and literary and musical productions and for such other categories as practical inventions and chess championships are in general agreement with the data for chemistry although with some minor variations It is significant that it appears almost as difficult to win a chess champion

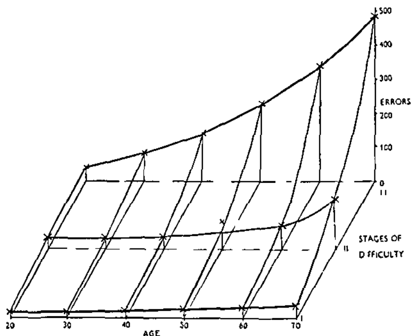


FIG 21 —The relations of errors, degree of difficulty, and age (After Kay, 1955)

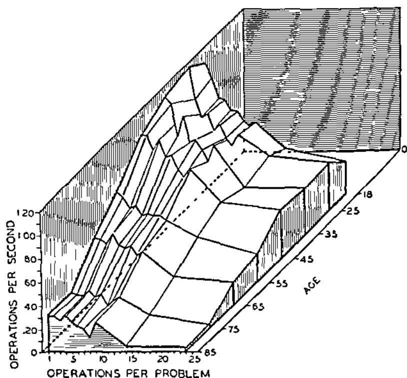


FIG 22 —The relations of addition rate, problem length, and age (After Birren *et al*, 1954)

ship as a major golf championship after the age of 50

In their number and variety Lehman's studies succeed in presenting an almost overwhelming picture of age decline in creativity An interpretation of these findings wisely stresses multiple causation rather than merely the influence of intellectual changes Decrements in physical factors, motivational changes and the preoccupation with other tasks, "resting on laurels," and adverse changes in family situations may all work to reduce both the quantity and the quality of later production A further factor mentioned by Lehman is that "younger persons tend to have a better formal education than their elders, they have grown to maturity in a more stimulating social and cultural milieu, and they have had less time to forget what they have learned' (1953, p 329)

CRITICISMS OF LEHMAN

Criticisms of Lehman's work have not been lacking, both on conceptual and on methodological grounds Perhaps the most comprehensive critique is by Dennis (1956*a*), who considers the following problems

1 The validity of choice of a man's 'best work" Is there a tendency to mention an initial pioneering achievement and to neglect later basic work necessary in developing it? (Many of Lehman's comparisons, however, are made on the basis of selections, by other judges, of distinguished work *in a field* rather than with reference to age)

2 Is there a bias against more recent contributions simply because of the greater difficulty of evaluating them? (This may apply at some points Nevertheless, to the extent that judges have a bias with reference to the age of a producer, they might be expected to favor the older and better-established person rather than the newcomer to a field)

3 Do changes in standards and in competition affect the picture? A person might have a better chance of doing something outstanding at the age of 30 than a few decades later, when he is confronted with many more competitors (This would seem more relevant to scientific than to artistic fields)

The considerations raised by Dennis do not apply with equal force to all of Lehman's research It is particularly worth noting that, when the quality criterion is made more stringent, the modal age tends to move downward rather than upward The more severe the test, the clearer the evidence for early creativity

Dennis' methodological criticism is chiefly in terms of the effects of differential longevity upon production Tables which combine the results for both long lived and short lived persons may underestimate creativity in the later years, because only a part of the sample is contributing in these years Lehman has attempted to make allowance for this in various ways, and Dennis concedes that he has done so successfully in those comparisons in which contributors are classified according to length of life This is shown in Table 10 Regardless of length of life, the age of greatest productivity remains in the thirties in Lehman's data.

OTHER STUDIES

A replication of the analysis in Table 10 has been made by Dennis (1956*b*) His sample, relatively small, consisted of nineteenth century scientists mentioned in a biographical directory and included all those who lived to age 70 or beyond For this group of 156 cases the average number of scientific papers published per decade decreased slightly in the sixties, but the most striking result was the relatively even rate of production between age 30 and 60 A fair degree of consistency is shown in the individual records, for those living to be 80, productivity in the thirties correlated 55 with productivity in the seventies

The difference between Dennis' and Lehman's data may be accounted for partly in terms of the period represented, evidence

is available from Lehman, of a trend in recent generations in the direction of earlier productivity This may be related to earlier identification of ability and more widely available resources for research Another factor may be the source in which names of eminent scientists are located, those who have achieved popular recognition in a biographical dictionary may be a somewhat different sample from those who are mentioned in textbooks or scientific histories, as in some of Lehman's principal studies

TABLE 10*

AGE OF GREATEST PRODUCTIVITY

Age at Time of Death	Percentage of Output Contributed during Successive Decades							
	Under 20	20–29	30–39	40–49	50–59	60–69	70–79	80–89
Prior to 50	5	32	50	14				
50–59		23	39	28	9			
60–64	1	17	32	27	20	4		
65–69		8	38	28	16	10		
70–74	2	15	36	28	13	6		
75–79		10	28	27	20	10	4	
80–84		12	32	28	15	9	3	1
85 or beyond		8	29	26	22	9	3	2

* After Lehman (1953)

However, some disagreement with Lehman s results is also to be found in a major investigation by Adams (1946) who examined the records of over four thousand scientists with reference to the age at which they did their best work By the criteria used, this varied from 37 in mathematics to the late forties in some of the social sciences Among psychologists Dennis and Girden (1954) found the highest rate of publication in the forties, with a decline of about 50 per cent in the sixties

AN EXPERIMENTAL APPROACH

These discrepancies obviously point to the need of further research One direction which such research might take is in experiments on creative production, as in a recent study by Bromley (1956) which was conceived as directly related to Lehman's investigations Bromley classified 256 subjects into four age groups which were similar in average social background and Wechsler Bellevue I Q These subjects were given the Shaw Test, consisting of wooden blocks which could be arranged according to a number of principles of logical order In terms of face validity, the test involves, without time limits, the mental operations of abstracting, serializing, and productive thinking as well as persistence, flexibility, and imaginative exploration Table 11 compares age differences in responses of the highest and lowest quality and also shows that the total output decreases with age less rapidly than the high quality output

Thus "creativity" in a normal sample appears to match Lehman's findings for very outstanding individuals Bromley, however, finds that his results depend chiefly on intellectual efficiency, for his total sample the mean for high quality responses correlates — 52 with age but only — 19 with age when the Wechsler Bellevue efficiency quotient is partialed out. In accounting for his own findings, Lehman has placed more stress on changes in physical factors than on those pertaining directly to intelligence level Bromley's results are somewhat similar to Rorschach studies (Prados and Fried, 1947, Chesrow *et al*, 1949) showing 'associative impoverishment" among older persons and to results with the Weigl test showing a decrease in generalizing ability (1957)

In a further study, Bromley (1957) designed a test of the hypothesis that age changes involve a reduction not merely in output ('performance potential') but also in autocriticism or "performance evaluation." Problem solving requires an output of ideas coupled with an ability to discriminate their relative worth. This latter function was examined, in three age groups, by means of proverb interpretation tests. The results showed significant differences between these groups. Bromley pointed out that the qualitative changes occurring normally in old age in the higher intellectual processes are similar to the deterioration shown by psychiatric cases at earlier ages.

TABLE 11

RESPONSES TO THE SHAW TEST (CREATIVITY)
(N=64)

	Age			
	17-35	35-51	51-66	66-82
Mean Social Background	2.95	2.86	2.84	2.92
Mean W B I Q	120.9	123.5	121.5	115.9
Mean total product on of responses	12.8	11.2	11.4	9.6
Percentage high-quality responses	72	68	57	36
Percentage low-quality responses	3	7	12	25

VIII. MEMORY

Memory is an important factor in intelligence tests particularly in connection with vocabulary and information subtests. As we have seen, older persons do relatively well on tests of this nature and hence we might infer that the phenomena of mental decline depend less on memory than on other factors.

Recent memory is often cited as a function marked by especially severe handicap in old age. However this is less a problem of retention than of reduced ability to form and integrate new connections. An additional problem arises from the mass of interfering material from past learning. Old people seem more forgetful partly because they have so much more to forget; repressions and emotional blockages are also operative, and to some extent (probably minor except in cases of pathology) there may be organic loss of traces due to deteriorative change in the nervous system. As compared with the vast amount of work in learning and memory in younger subjects and in animals, this topic in its various ramifications is very poorly developed in gerontology. What is required is a much more intensive program of experimental work such as is now under way in a small number of laboratories.

In an early study Jones *et al.* (1928) reported the results of memory tests with 420 subjects aged 10-59. The tests were based on motion pictures given in eight small communities in Vermont, selected, by a number of criteria, as a representative sample of rural communities in that state. Attendance was recruited through printed placards announcing free admission and that in return for the entertainment the audience would be requested to answer "a brief and interesting questionnaire," which was in the form of a specially printed test

It was not stated that the questionnaire would in part be related to the moving picture, this portion of its content may therefore be

curious throng of farmers and villagers, in these thrifty New England communities a free show proved a dependable means of gaining popular interest and support [Jones *et al*, 1928 p 227]

Figure 23 gives age curves for immediate recall on two motion pictures one of these was a film from the Yale Historical Series" and one a romantic drama The items

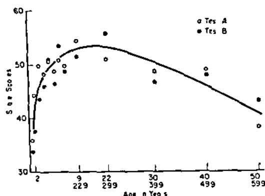


FIG 23 —Age medians for two tests of immediate recall for motion pictures (based on the average and standard deviation for the age group 16–50)

dealt with all aspects of these pictures verbal material from the subtitles as well as pictorial material and with incidental episodes as well as with the plot In each test raw scores have been converted into T scores based on all members of the age group 16–50 The general characteristics of the curve are almost identical with that for the Army Alpha Examination in the same population, except that the memory scores show a tendency for a more rapid decline after age 50 In the age group 40–45, 95 per cent exceed the median for the age group 55–60

A test on a third motion picture, a 'western," was given to 152 subjects immediately after the picture and to 88 subjects after a delay interval of a week Scores in this unannounced delay test were lower than in the immediate test in all age groups beyond 25, but the differences were too small to be significant The deficiency of older adults seems to be chiefly in the registry and immediate recall of this material rather than in accelerated losses during the following days

Two methods were used to eliminate the speed factor in test performance a rescoring of the test on the basis of the first two-thirds of the questions and a rescoring in terms of proportional credit (percentage of correct answer of those attempted) The resulting age curves were substantially the same as in Figure 23, leading to the conclusion that "speed may differentiate the age groups, but when this factor is removed, the remaining functions involved in the test are about equally differentiating This analysis, however, has dealt only with the factor of speed in test performance, and not with the speed of perception and other processes that may be involved in apprehending the content of the motion picture" (Jones *et al*, 1928, p 239)

In a monograph from Hiroshima University, Kubo (1938) has examined age differences in rote memory from 70 to 90 in 347 men and women "in good health" The tests involved the reproduction of word lists three to seven words in length, presented orally In the tables which he presents it is apparent that an age decline does not become especially marked until the late seventies in women and the early eighties in men The nature of the sampling, with regard to age and sex, is not described

A report by Pacaud (1955) has previously been referred to in connection with an extensive study of French railway employees Several memory tests were included in this test program *Memory for* paired associates was shown to decline with age, with a marked break between the early and late twenties Memory span for digits rose during the teens to a peak in the early twenties, then declined sharply to the late twenties, and more gradually thereafter

Age differences in a series of eleven memory tests were studied by Gilbert (1941) in two groups of younger and older persons who were matched for vocabulary level This procedure should eliminate the possible influence of educational factors As an age sampling the older persons were on the whole probably slightly superior to the younger group Significant score differences were found for all tests between the twenties and sixties (favoring the younger) These were, however, differential with regard to ability level The more intelligent have better memories when they are young and retain these abilities more effectively as they grow older

In the important early study by Willoughby (1927) (discussed above) one of the mental test items was supplemented by an incidental recall test After completing a digit symbol substitution series the subjects were required to recall the combinations without referring to the key This constituted a test of incidental memory, since the original test had not been presented as requiring memorization Although the curves for the original performance and for incidental recall are similar the latter has a much earlier peak (Fig 24) The age differentiation is so marked that Willoughby was forced to the conclusion that "incidental learning is a function of youth"

IX Mental Physical Relationships in Aging

The picture of associated mental and

which deal with organic injuries conceived as reducing the efficiency of mental functioning These changes may be thought of in terms of gross injuries illness and damage to any vital organs, circulatory defects, or cumulative minute insults to the structure and function of the nervous system

Hypotheses may emphasize environmental factors environments low in the socio economic scale tend to be characterized by poor hygiene, inadequate nutrition, a higher morbidity rate, and reduced medical service In addition, poor environments may be weak in intellectual stimulation and in facilities for the maintenance of intellectual activity Thus both physical and mental handicaps may be generated

Psychological hypotheses, on the other hand, emphasize psychological losses as vectors affecting physical health and hygiene or the effect of cumulative personality disturbances upon both mental and physical functioning

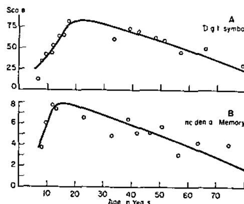


Fig 24 —Age means for digit symbol substitution and for subsequent incidental memory

Finally, a biological hypothesis rests upon the assumption that favorable traits are intercorrelated Common organic factors, genetic in origin and expressed through maturation and later involution, account both for overt physical regressions and for structural and metabolic changes within the body, especially in the nervous system, which are related to decline in mental process These hypotheses are not mutually exclusive Partly because of their complexity and overlap, very little has been done with them as yet in systematic research One of the most promising lines of investigation is in the study of the aging of twins and of their siblings, as in the work of Kallmann (1956), with the possibility of analyzing genetic factors in physical and psychological maintenance

In numerous studies of children and ado-

lescents meager results have usually been found with regard to the relation of intelligence to illness records, to assessments of physical condition, or to measures of size or physical ability Where correlations are reported (age constant), they are usually below 30 and quite often too low to be significant

At the later ages, however, factors capable of influencing each other have operated over a much longer period, and often with environmental reinforcement or with reinforcement from the subject s own attitudes Thus at these ages we may have a more promising field for the application of theory and for findings of practical value

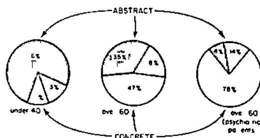


FIG 25 —Proportions of abstract and concrete solutions in different groups (abstract responses are shown as shaded areas in two gradations the higher grade being indicated with vertical lines)

We will continue to expect reports such as those of Chesrow *et al* (1949), who found, among older men, no relation between physical condition and intelligence test scores But in a broad sample of subjects this degree of specificity is not likely to be maintained at all ages Case histories will show, in the later years, many individuals in whom physical and mental changes are interrelated or are clearly to be seen as an expression of common factors in senescence

ORGANIC IMPAIRMENT

Considerable attention has been given to the mental characteristics of persons with known pathology, such as cerebral arteriosclerosis or senile dementia If they differ from normals of the same age merely by minor quantitative gradations, the inference might be offered that normal decline is in itself an outcome of organic changes perhaps similar in nature but of less critical degree

Goldstein and Scheerer (1941) have proposed that brain impaired persons can be differentiated by their greater tendency to assume concrete attitudes and to resist abstract procedures in problem solving Rightness or wrongness of answers may be less important, in this connection than the degree of abstraction shown

Hopkins and Post (1955) tested this hypothesis in a comparison of 49 psychiatric patients over 60, matched for age and sex, with the same number of subjects without mental disorders A group of younger normal adults was also used

Figure 25 shows the differentiation of the three groups on the Goldstein Scheerer Cube Test A concrete response in all attempts occurred twice as often in the psychiatric group as in the normal group of older persons But age differences are much more striking than the differences between patients and non patients at the older ages. In the Weigl Color Form Sorting Test Thaler (1956) has obtained similar evidence of more concrete performance at the later ages

The Halstead Impairment Index (1947), designed to differentiate cases with brain damage has been successful in distinguishing such cases from hospital groups without brain lesions In the brain-damage cases, Reitan (1955*a*, 1955*b*) found a slight relation of the Impairment Index to age ($r =$ 23) In a control group, however, this relation was much more marked ($r =$ 54 $\eta =$ 61), and beyond age 45 mean scores fell beyond the criterion level used by Halstead to distinguish frontal brain–damaged subjects Thus an instrument constructed for the purpose of registering gross changes in the brain also proves highly sensitive to normal age changes It should be pointed out, however, that Reitan's control group was not ideal for this purpose, since it contained a number of neurological cases (paraplegics) and of subjects with person

ality disturbance If these results are verified in a non hospital group, it would be consistent with a theory of intellectual aging in terms of cumulative minor cerebral impairments, although this is of course not the only possible interpretation

It is not within the province of this chapter to review pharmacological or endocrine research in relation to mental functioning or comparative studies in different pathological groups Research on the electroenchepalogram and on cerebral physiology has also been excluded These areas, however, hold the most promising topics for future basic research on the aging of mental functions

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XXI

Drives, Expectancies, and Emotions

JACK BOTWINICK

I Introduction

We know what aging does to certain drive states we know how quickly elderly persons mobilize for simple response, we are learning more and more about the effects of prior experience in the aging process, and we know a little something about the emotional life of the elderly This chapter deals with these aspects of general responsiveness under the headings of drives short term expectancies long term expectancies and emotions

In spite of what we do know basic questions are in need of answers Are older persons, as compared to younger ones more prone to anxiety or to states of anger? With age do these states take longer to build up or to dissipate? Do patterns of responsiveness change with age? Is a situation that is feared by the young also one that is feared by the old? Are age changes in responsiveness consistent among various phyla and species? These and many other questions cannot be answered with precision at the present time because of three main reasons The first reason is simply that the field of study is relatively new The second reason is that the necessary tools for investigation and appropriate experiments with young subjects have not been developed The third reason is that age comparisons involve many methodological problems which as will be seen often give rise to interesting theoretical issues

Drives expectancies, and emotions as aspects of general responsiveness are related in that they are internal conditions of the organism inferred from changes in specific behaviors The conditions and behaviors may be related to changes in the environment but not necessarily Drives, expectancies, and emotions have influence on subsequent behavior because they function as determining, motivating, or activating agents Thus, while the observations that are reported in this chapter are of age changes in overt behavior, the concern is with age changes in the inferred internal events

A distinction is made frequently between age changes and age differences Interpretations of age changes are made usually in the course of longitudinal studies, while those of age differences are made in cross-sectional studies It seems to the present writer, however, that the respective interpretations should not be so much a function of method as of the extent of influences of society or culture If the behavior under observation is, for example, interest patterns that are primarily culture oriented, then findings in either longitudinal studies or in cross sectional studies may be discussed in terms of age differences On the other hand, if the observed behavior is not related to cultural or societal influences, or is related relatively little, findings may be discussed in terms of age changes regardless of the method used This formulation suggests that all aging studies on infrahuman subjects where precise laboratory control is arranged may be interpreted as age

changes It is clear, however, that age differences and age changes may be interactive in any one study and make for errors in interpretation These errors would be found in both longitudinal and cross sectional investigations

In this chapter convention is adhered to for the sake of clarity Drives short term expectancies long term expectancies and emotions are discussed as age differences when the method is one of cross sectional age comparisons and as age changes when the method is one of longitudinal age comparisons This is the case regardless of the estimated influence of culture or society Studies of age differences and age changes in various phyla and species suggest the limits of plasticity of behavior of elderly organisms In this way they provide a base to evaluate and develop procedures that maximize productive output of the elderly

II Drives

Definition

Knowledge of drives comes from two sources one is information concerning the past history of the organism the other is observation of behavior For example if we know that a person has not eaten in 3 days we infer that he has a hunger drive that will lead him to eat If we observe a person eating ravenously or hear him say that he is hungry we also infer a hunger drive In similar manner we infer extent or strength of drive 3 days of not eating or consuming large quantities of food would be indicative of greater drive than 3 hours of not eating or consuming just a bit of food We may of course be inferring incorrectly in both situations Related to the eating may be learning or personality variables operating independently of states of physiological deprivation or arousal In the absence of other information however, hunger drives may be our best inferences If we know the past history of the organism and if we observe the behavior, our inferences are more likely to be correct

Drives, therefore, will be considered as constructs representing internal conditions of the organism that result from states of physiological deprivation or arousal In this context, drives are unlearned and lead the organism to behaviors frequently assumed to satiate or to reduce these physiological states

Theoretical Considerations

Referring to data (Margolin and Bunch, 1940) that will be discussed in some detail, Munn (1950 p 90) reported that the strength of hunger drive is less for mature rats than for prepubescent rats In addition, the younger group reaches maximum drive strength in 3 days, while the older group does not reach maximum strength until 5 days Results such as these give rise to methodological dilemmas when their significance or the role they play, is assessed in the aging process For example, if mature rats reach maximum hunger drive in 5 days and immature rats reach it in 3 days how should rats of different ages in learning studies be equated for drive? That is to equate drives, should mature rats be maintained on a 5 day food deprivation
3 day

is a given amount of food reward or reinforcement more effective because of this? Should the mature rats, therefore be given more food reward and kept hungry longer than immature rats? This topic is discussed in greater detail by Jerome in chapter xix

There are other problems in studying the role of drive in aging studies It was said that presence and extent of drive are determined from knowledge both of the amount of deprivation and of characteristics of the behavior or performance under observation In comparing mature and immature rats, not only was the number of days of food deprivation known, but also behavior was measured in terms of number of crossings—the more crossings the more the strength of drive However, from stud

ies of general activity that will be de scribed, we may expect that younger rats with low drive will cross more frequently than senescent rats with equally low drive Thus the strength of a behavior may vary with age irrespective of the conditions of deprivation, but the behavior itself may be related to extent of drive within an age group A more apparent illustration, per haps, is an inference of drive based on response latency or speed We know that older organisms are slower than younger ones (e g, Brody, 1940, Birren, 1955*a*) and that drive is a function of the measures of response May we infer an age difference in hunger drive if two age groups are different in the time taken to run down a straightaway, even though speed of running in both groups is functionally related to hours of food deprivation? A similar prob lem was implicit in a recent study by Birren and Kay (1958), who measured swimming speed of albino rats in three age groups They also studied the temperature of the water or the intensity of the drive condition Minimum swimming times were observed in the temperature range 16°–

ference in performance that was not re lated to drive level

The investigation of age differences in drive states has relevance that goes beyond the methodological considerations inherent in learning studies This is indicated in a neat distinction made by Larsson (1956), who suggested that the problem "is not to be considered simply as a drive quenched by a motor response but it is a unity of reflexes whose spatial and temporal relationships *distinctively reflect changes in the* internal and external world of the animal " The point is that, in studying age differences or changes in drive states, there may be more profit in emphasizing altered internal events than factors that require dif ferential 'quenching" for purposes of learn ing experiments

Investigations of drive states, therefore, have significance for aging in two ways First, and perhaps most important, in vestigations should yield information re garding changes or alterations of internal events with age Second they should clarify problems and difficulties that may be inherent in aging studies of learning and problem solving While these two ways may not be completely independent, they do focus on different aspects and should result in a more thorough understanding of un derlying processes and of determining and satiating characteristics of behavior

Literature

Drives that have been investigated in re lation to age will be considered here These include hunger, sex, activity, and light aversion Drives that to the writer's knowl edge have not been investigated in relation to age will not be considered Among the latter are thirst sleep, maternal, and hoard ing drives

HUNGER

The general impression that there may be differential age effects on behavior due to varying amounts of food deprivation is not uncommon, but it appears that this has been investigated systematically in only one published study In a comprehensive examination of the relation between hunger drive and age, Margolin and Bunch (1940) used 240 male albino rats in each of three age groups 30–40 days, 150–75 days, and 300–350 days These groups will be re ferred to as "prepubescent," "postpubes cent," and "adult" rats respectively

The obstruction method was used in their study, and the measure of hunger drive was the number of crossings over a 10 inch *wire mesh runway from a starting* compartment to another one where food was found Each of the three age groups was divided into four subgroups of 60 rats, and each subgroup was subjected to a different amount of shock over the wire mesh runway, 0, and approximately 0 08, 0 12, and 0 16 *milliampere There were three conditions* of food deprivation for each age group

and for each shock condition subgroup, thus making 20 rats available for each specific category of age food deprivation, and shock intensity The two older groups were deprived of food for 1, 3, and 5 days The prepubescent group was found to be weakened by a 5 day deprivation schedule therefore the drive conditions for this group were 1 2 and 3 days Individual animals were given a 10 minute adaptation period and then run in the experiment for 30 minutes After each crossing the rat was permitted to taste the food and then was placed back into the starting compartment Crossings were recorded for each 5 minute period

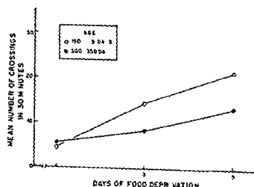


FIG 1 —Mean number of crossings of a wire-mesh runway by albino rats to obtain food Data are of animals in two age groups under three levels of hunger drive (After Margolin and Bunch, 1940 pp 11 and 16 Tables 2 and 3)

The largest number of crossings were made by prepubescent rats the next largest by the postpubescent rats, and the least crossings by the adult rats The difference between the two younger groups was much larger than between the two older groups With 1 day of food deprivation the two older groups made almost equal number of crossings about four or five while the prepubescent group made close to eighty crossings To determine the role of hunger drive in relation to age, it would be desirable to have information of crossings with near zero hunger The two older groups made similar crossing scores with 1 day of food deprivation, and thus the increased time of hunger (3 and 5 days) is referrable to a common index of crossing This common reference serves a similar purpose, as would information of crossings at near zero hunger There is not a common or obvious reference point for the prepubescent group This consideration, plus the fact that the youngest group did not have 5 days of hunger, suggests that comparisons between the two older groups are more pertinent for the present purposes than comparisons that include the prepubescent rats

Frequency of crossing an electrified grid to consume food may be an adequate measure of hunger drive, but frequency of crossing a non electrified grid appears to be a more appropriate index as far as age differences in drive are concerned The reason is that there may be differential age reactions to shock that are independent of hunger drive This possibility was also suggested by Margolin and Bunch (1940) Therefore, the data of primary concern are of non shock crossings of the two older groups These data are presented in Figure 1 as the mean frequency of crossing during 30 minutes of observation for 1, 3, and 5 days of food deprivation

The data in Figure 1 were subjected to an analysis of variance by the present writer Drive level was found to decrease with age This decrease became more manifest with increased hunger The age difference in drive level and the interaction of age and days of deprivation were significant beyond the 01 level of confidence The inference for learning studies in which albino male rats approximately one half year of age are compared to samples 1 year of age is that food deprivation longer than 1 day may produce groups that are unequal in drive strength In regard to alterations with age it is not known whether the primary factor is one of locomotion food "desires" or state of health due to starvation

SEX

Human—It is significant that, with the manifold of variables that are related to

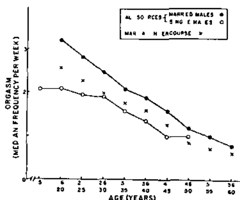
human sexual behavior, Kinsey *et al* (1948, p 218) concluded that "in the sexual history of the male, there is no single factor which affects frequency of outlet as much as age" Their data were obtained by way of interview which was naturalistic in intent and are the most comprehensive in the published literature

The sexual behavior of the human male was analyzed in terms of six sources of orgasm, and the total of these six sources was referred to as total sexual outlet Kinsey *et al* found frequency of total sexual outlet to be maximum in the teens and to drop gradually with advancing age Figure 2 indicates that, in their sample population, this was also the case for frequency of marital intercourse, one of the six sources of orgasm In general, there was a more or less corresponding age decrement for each of the six sources of outlet Kinsey *et al* reported that a significant aspect of the age decline in frequency of orgasm is that it was found to be gradual and to have little difference in rate of decline between each 5 year age group

Along with the age decline in frequency of orgasm are related changes Kinsey *et al* found that, with advanced age, there was increased impotence and decreased 'erotic responsiveness," ability to reach repeated climax, frequency of morning erections, duration of erection, angle of erection, speed of reaching full erection and amount of precoital mucous secretion

One finding most prevalent in aging research is that there is more variation within advanced age groups than within younger groups Just the opposite result was found by Kinsey *et al*, who reported that range of variation was greatest in the youngest groups and was gradually reduced with successive age periods This was true for total sexual outlet and for most of the six sources of orgasm One explanation may be that some younger individuals are extreme in high frequency sexual activity This drops with advanced age and can account for the increase in homogeneity

The sex drive in the human male decreases with age, but the origin of the decrease is not well established Undoubtedly, the primary factor is an altered physiological capacity, but it is 'affected also by psychologic fatigue, a loss of interest in repetition of the same sort of experience, an exhaustion of the possibilities for exploring new techniques, new types of contacts, new situations" (Kinsey *et al*, 1948, p 227) In numerous cases change of sex partners and sexual techniques increased frequencies in older males, although in a relatively short time previous rates were re established The decrease with age may also be related to decreases in availability



of contacts In any case, the relative contribution of social and biological factors in the sex drive of the human male is not clear

In the human female the problem of determining the effects of age on the sex drive is more complex than in the male There are greater cultural restrictions on female sexuality than on male sexuality In addition, the male rarely fails to reach orgasm in such activities as masturbation or coitus, while "a considerable portion of the female's sexual activity does not result in orgasm' (Kinsey *et al*, 1953, p 45) From the data of Kinsey *et al* (1953, p 353), it appears "there is little evidence of any aging in the sexual capacities of the female until late in her life"

There was an observed decline in frequency of marital coitus by the female, but this was attributed to sexual aging of the male On the other hand, frequency of premarital coitus for those females who were not continent reached a peak in the twenties and stayed level until the middle fifties or later Frequency of premarital intercourse however, is probably not a good index of female sexuality since the frequency is related to age of marriage cultural restrictions and perhaps a selective population of aging spinsters Kinsey *et al* (1953 p 146) suggested that frequency of masturbation may be more appropriate as an index of female sexuality because it depends primarily on the physiologic state and the volition of the female Frequency of masturbation in married women is only 'a bit lower than the frequencies among the single females and among those who had previously been married" (Kinsey *et al*, 1953, p 144)

In comparing the sexes with respect to frequency of masturbation rates were found to be lower in the female population However, unlike the case with males frequency of masturbation of females declined only slightly with age (Kinsey *et al*, 1953 Fig 149, p 716) The indication therefore is that sex drive in the human female ages slowly and to a relatively small extent

Animal —Controlled observations of sexual behavior in which there is systematic manipulation of independent variables is possible, of course only with lower animals Larsson (1956 pp 77–100) performed a series of experiments on sexual behavior of the male rat and included in this series an investigation of the effects of aging

The general method was to admit a female rat to the cage of the male When the female is so admitted, intromission is begun and stopped, to be started again and continued in a series until ejaculation After ejaculation, the refractory period is begun This period is one of recovery during which time the male is not responsive to sexual stimuli The refractory period is terminated by the next intromission Measures of sex drive are number and rate of intromissions and ejaculations and duration of intromissions and refractory periods

During the period before puberty sexual behavior short of ejaculation was found to be present Ejaculation appeared in puberty From puberty to adulthood there was a decrease in the number of intromissions preceding ejaculation, the duration of each series of intromissions, the number of intromissions per minute, and the refractory period There was an increase in number of ejaculations achieved

Ejaculations per hour of observation increased steadily to a maximum mean level of 5 7 in rats of about 12 months of age. This level was more or less sustained to about 20 months of age, at which time there was a sharp decline in ejaculation rate. Duration of the series of intromissions was shortened with maturity and became prolonged in advanced age The refractory period was prolonged after 22 months The increase in frequency of ejaculation from puberty to about 12 months takes place, apparently, during darkness only During periods of light the mature rat is less active sexually (Larsson, 1958*a*)

Waning sex drive of the male rat as a result of age was found with another technique Slonaker reported that male rats in revolving cages are more active than usual when placed near female rats in separate cages With increasing age beyond 550–650 days, the effect of the female on the male "became less and less and finally ceased (1935, p 181)

There is excellent evidence that the relation between sexual drive and age is the result of changes in both external and internal environment The role of external environment is made evident by the finding that the sexual adequacy of senescent rats increased with collective copulation The number of ejaculations for 25 month-old rats was 2 1 per observation hour during isolated copulation and 3 8 during copulation of three couples in the cages The number of intromissions also increased with

collective copulation, but the intromissions per minute and the refractory period did not (Larsson, 1956, pp 151–56) This increase in sexual potency of the senescent rat with collective copulation may be similar to the temporary increase in potency of the elderly human male when sex partners are changed (Kinsey *et al*, 1948)

There is other evidence indicating environment affects sex drive For example, Beach (1942) found that male rats raised in individual cages were more likely to copulate than rats reared in cages with either male or female rats In similar manner, Kagen and Beach (1953) found that male rats reared in individual cages ejaculated more frequently than males periodically exposed to females or to other males The isolated and exposed animals, however, were not different with respect to occurrence of copulation The decrease in frequency of ejaculation of the exposed males was explained by learned habits which interfered with complete sexual behavior The habits were learned in the course of playful contact with other animals Larsson (1956 pp 86–93) did not find a reliable difference between experienced and inexperienced rats in frequency of ejaculation but reported that extremely high rates were more frequent with experienced rats

Different results were reported with male guinea pigs by Valenstein *et al* (1955) They found that guinea pigs raised in isolation had difficulty in mating They concluded that effective patterns of sexual behavior are organized in the course of early experience The discrepancy in results be

mothers and siblings at the very young age of 14 days (Beach, 1958) Again he found that rats reared in individual cages copulated normally Beach concluded that genetic differences between rats and guinea pigs may be the reason for the different effects of early experience in the two species

Changes in sexual activity as a result of changed environmental conditions, whatever they may be, are undoubtedly mediated by some of the same alterations of internal events that are known to be induced by more direct means The endocrine and nervous systems are significantly related to sexual behavior, as is well documented by studies and reviews of the literature (e g, Beach, 1947, 1948) An important research problem is to determine the effect of age changes in endocrine and neural function on sexual behavior If, as was suggested by Soulairac (1952), frequency of ejaculation is dependent primarily upon hormone level, while indexes of intromission and refractory period are dependent upon status of central nervous system, differential age changes of the components of total sexual behavior may be a reflection of differential modifications of internal events with age Evidence, according to Larsson (1956, p 100), implicates both the endocrine and the central nervous systems in sexual aging, with emphasis on the nervous system

ACTIVITY

Animals display spontaneous activity that appears to be undirected It is associated with a drive that has been referred to as a general activity drive or an exploratory drive As an activity drive, the emphasis has been on internal factors, while as an exploratory drive, the emphasis has been on external stimulation (e g, Montgomery, 1953) Spontaneous activity can be thought of as drive induced behavior which may satiate or reduce stimulation from both internal and external origins

In general, it has been found in experiments on spontaneous activity of the white rat that activity in revolving cages increases with age, and then decreases Slonaker (1907) placed the age of maximum activity at 87–120 days and then at roughly 300 days (1912) Richter (1922) was in agreement with Slonaker's first study, with a finding of 100 days as age of maximum

activity Shirley (1928) found peak activity to be at 210–70 days, which is in relative agreement with the data of Slonaker's later study

An exception to the generalization of first a rise and then decline of activity with age is in a study by Anderson and Smith (1932) They found activity to decrease from age 31 days to 151 days and gave as possible explanations of this apparent discrepancy with the previous literature that activity is usually recorded for 24 hours and they recorded activity for only an hour In addition their rats were well fed and therefore perhaps less motivated in relation to age This latter suggestion was argued against with their own data on a sample of rats that were nutritionally deficient and still showed the decline in activity with age It could be indicated here that with extrapolation of the data of Margolin and Bunch (1940) the lack of hunger drive might be expected to work in favor of the older rats and not the younger

Two relatively recent studies are most pertinent for the present purposes One study is by Browman (1942) who, although concerned primarily with the relation between activity and conditions of light and darkness had data on aging He used an inbred strain of 104 albino rats, 40 of which had both eyes removed during their first day of life Activity was tabulated for male and female animals of both seeing and blinded groups under various conditions of light and dark Animals were placed in revolving drum cages at 28 days and allowed a minimum of 7 days to become adjusted to the experimental conditions

It was found that greatest activity occurred between 70 and 100 days in the rats that were observed until 9 months of age Animals younger than 70 days and older than 100 days tended to be less active than the pubescent rats The conditions of seeing and darkness were studied in animals less than 100 days of age and these data will be referred to later

Jones *et al* (1953) found that there is an interaction between age and experience as it relates to activity. Five age groups of 89 male Sprague-Dawley rats were run in wheel cages for 7 consecutive weeks The five age groups were 57, 72, 100, 142, and 212 days at the start of the experiment It was found that activity decreased with age and increased with experience or with time in the work cage Age and experience interacted such that, the older the initial age of the group, the shorter was the time required to reach maximum activity level These data may be seen in Figure 3 Unlike previous investigations, no long term cyclic variation in activity was found

As already indicated, the results of all but one study were compatible with the generalization that, in the rat, there is an increase of spontaneous activity from birth to at least puberty, after which time activity declines In regard to this decline with age it is not known at present whether the primary factor is one of change of input from the external environment or of change of internal events Changes in input may be due to age related alterations in exteroception, as for example, vision, while changes of internal factors may be due to age related alterations in musculature, proprioception, endocrine function, and more central neural mechanisms

An important experimental problem is the determination of the relative contributions of these changes with age to the decrease in spontaneous activity Hunt and Schlosberg (1939) reported that male rats with eyes enucleated were less active than normal males, while Browman (1942) found that enucleated male and female rats were more active than their normal controls In addition, darkness made for greater activity in seeing rats than did light The difference between Browman's results and those of Hunt and Schlosberg may be due to the methods used to measure activity It is more likely, perhaps, that the difference in results may be accounted for by a difference in the age of the rats that were used confounded with the age of blinding Browman's study was based on animals aged 100 days and less blinded during

their first day of life Hunt and Schlosberg's rats were blinded at ages exceeding 200 days The interaction of age and experience is one study of many which might shed light on whether the decline in activity with age is due primarily to changes in external stimulation or to internal events Research of this kind may help in discovering age changes in more specific variables grouped within the broader categories of external or internal events

The investigation of activity in relation to age is also of interest in a different context Anderson, in chapter xxii, discusses how people of different ages organize and direct their available energy

LIGHT AVERSION

Albino rats avoid light and will solve problems or learn tasks in order to do this While the compelling effect of light is not very strong, it is related to the intensity of light (Jerome, Moody, Connor, and Ryan, 1958) and amount of time in the dark (Jerome, Moody, Connor, and Gremler, 1958) Light aversion, therefore, is a drive because it leads to behaviors which appear to be unlearned and which are related to amount of stimulation and its reduction There may or may not be human analogies to this light aversion of albino rats

In an aging study employing the method of light aversion as a drive (Botwinick, Jerome, Birren, and Brinley, 1957), 48 Sprague Dawley rats were divided equally into four groups by sex and age (approximately 1 and 2 years) Rats were run individually in a light-escape apparatus requiring little or no learning Simple passage through a single door hinged to the roof of the test cage was all that was required

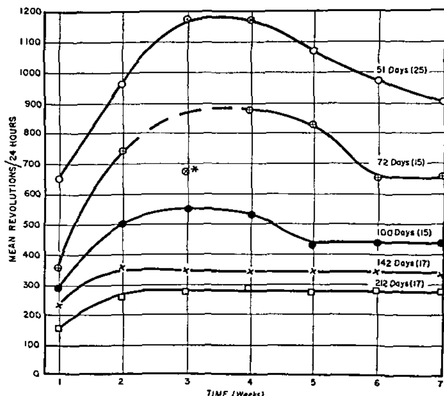


FIG 3 —Mean revolutions per day of rat activity wheels as a function of age of rat and time in wheel cage (After Jones *et al*, 1953)

to avoid light. Darkness or avoidance of light was the only apparent reward It was found that no age sex, or age sex interaction factors were related statistically to light avoidance The conclusion from these data is that with age at least from 1 to 2 years in the Sprague Dawley rat, no alterations occur that seem to be related to the drive of light avoidance From the point of view of learning studies in which Sprague Dawley rats of these ages are compared, it does not appear necessary to take special precautions to equate age groups for the drive of light avoidance, at least with the intensity of light and time in the dark used

III Expectancies (Short Term)

Definition

The expectation of an environmental event and the preparation for this event are aspects of general responsiveness or arousal The better prepared a person is to respond, that is, the more accurate is the anticipation of what is coming next and the sooner a response pattern can be organized the quicker and more appropriate will be the response itself In crossing streets driving cars, and in work calling for high speed operations adequate preparation or expectancy, and therefore quickness of response, can be of utmost significance This is especially true with the elderly, where a generalized slowing may be superimposed

The expectancy to respond within short time intervals has been studied in reaction time (RT) experiments In these experiments the short time intervals are called preparatory intervals (PI) or foreperiods The PI is the interval of time between an initial warning or preparatory signal and a succeeding stimulus that calls for a response RT expectancy, therefore, is the anticipation set preparation, or organization to respond within the PI PIs studied have ranged in time from less than 1 second to 25 seconds

Literature and Theoretical Considerations

Expectancy, defined by the conditions of the reaction time experiment, has a relatively long history going back at least to 1911, when Breitwieser studied what he called "state of attention" With the same amount of time of 'attention," his subjects differed in 'preparedness to react" Other early experiments were by Woodrow (1914, 1916), who also was concerned with attention

Since that time there have been many experiments dealing with this problem, and most have been very competently reviewed by Gibson in 1941 It is not necessary to examine here all these studies, since they are of background concern and have only indirect relation to problems of aging It is only necessary to mention here that, with respect to the PI in the RT experiment, Gibson categorized four principles One was that the PIs in a regular sequence or series make for shorter RTs than do PIs in an irregularly presented series (Woodrow, 1916) A regular series comprises one PI repeated over and over again until a second is so repeated and then subsequent PIs so repeated An irregular series comprises several PI's presented in random fashion

A second principle Gibson listed was that if the RTs are made repeatedly for very long to PIs of a regular series, they will approach zero time and it will be dif

preceding the stimulus These anticipatory reactions however, may be prevented to some degree if there are catch sequences in the series, that is, only the warning signal is used not the stimulus

the greater
PI and
e longer

the RT This principle is based on a study by Mowrer (1940)

A fourth principle that Gibson categorized may have to be extended mainly due to studies subsequent to his review The

principle is that RT is related to the absolute length of PI so that PI's shorter and longer than approximately 2 seconds make for long RT's Recent studies by Drazin (1958), Klemmer (1956), and Botwinick, Brinley, and Birren (1957) suggest that RT is a function of the *relative* length of the PI in an irregular series rather than the *absolute* length PI's shorter and possibly longer than the PI of central tendency (e g, median), whether it is 2 seconds or not, make for longer RT's Woodrow's early work (1914) also indicates this result That RT's to a second stimulus are as quick as to a first stimulus when the two are separated by only 0 25–0 35 second, is seen in a recent study by Davis (1956)

A context principle relating RT to PI's in the context of other PI's in the irregular series is applicable probably, only within certain limits Although there are no data bearing directly on this issue it is not likely that RT would be optimum with a very long PI (e g, 20 seconds), whether or not it were the interval of central tendency A modified context principle is indicated therefore, that relates RT to some combination of absolute and relative PI length

There is a fifth principle to be listed It was said that PI's in a regular series make for shorter RT s than do PI's in an irregular series This principle holds only for relatively short PI's There is a PI length longer than which RT s in irregular series may be shorter or of similar magnitude than RT s in regular series The exact PI length for which this is the case depends among other things, upon the type of sample population that is tested Long PI's involve the problem of maintaining set while short PI s involve the problem of developing set (Huston *et al*, 1937, Rodnick and Shakow 1940)

AGE DIFFERENCES IN EXPECTANCY

Botwinick, Brinley, and Birren (1957) were concerned with the influence of age on short term expectancies Two age groups were tested for simple auditory RT with the use of eight different PI's in an irregular series The range of PI's in the series was from 1 to 6 seconds The two groups, comprising 27 men each, had mean ages of 68 and 27 years The older group ranged in age from 61 to 83 years, the younger group, from 20 to 36 years

The general method was a comparison of the two age groups statistically with respect to the functional relation between

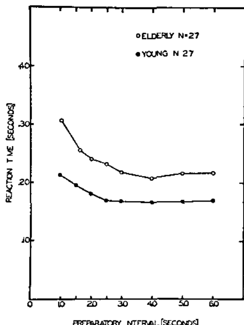


FIG 4—Reaction time as a function of the preparatory interval for male subjects in two age groups 61–83 and 20–36 years (After Botwinick Brinkley and Birren 1957)

RT and PI These data may be seen in Figure 4 An analysis of variance indicated that the functional relations were different between the two age groups in that the largest age difference in RT resulted from the shortest PI (1 second) or shorter PI's in the series The smallest age difference in RT resulted from the PI of about 4 seconds

Four hypotheses or interpretations, not necessarily mutually exclusive, were derived from these data One hypothesis is that in the course of aging there is an in-

crease in the amount of time required to develop a state of optimum expectancy or to organize a response The basis for this hypothesis is that the age differences in RT were greater when relatively little time was allowed for preparation (e g , PI = 1 second) than when more time was allowed (e g PI = 4 seconds) This hypothesis is compatible with the concept that RT is a function of the absolute length of the PI It is not incompatible however, with the concept that RT is a function of relative PI length when only short PI's are considered

A second hypothesis is related more to the concept that RT is a function of the relative length of the PI in the irregular series This hypothesis states that larger age differences with the shorter intervals are explainable by the time required to recover from or to reorganize as a result of an overestimation of the duration of the PI For the different age groups absolute lengths of the PI's in the series are equally long or short with respect to the time required to organize the response or to develop the expectancy The expectancy is of the PI of central tendency (e g median), so that RT is longest when the PI in the series is most different from the median PI This generalization is not incompatible with Mowrer's data (1940) When the PI is most deviant from the expected PI (PI of central tendency) because it is the longest in the series, then there is time to recover from the inaccurate expectancy, that is underestimated interval When the presented interval is the shortest in the series, then there is least time to recover from the inaccurate expectancy that is, overestimated interval In Figure 4 the largest age difference in RT with the PI of 1 second may be explained by the hypothesis that the older group required more time than did the younger group to correct for the overestimation This hypothesis was supported by the curves in Figure 5 when RT was plotted as a function of the difference between adjacent PI's in the series Age differences in RT were largest with those differences between adjacent PI's where little time was permitted for correcting overestimated intervals Clearly, this may hold only to a particular PI length As indicated, very long intervals may involve the problem of maintaining set or attention This becomes a type of vigilance problem

A third hypothesis suggested in the study by Botwinick, Brinley, and Birren (1957) is that there is a general slowing with age that is reflected in various conditions including the time required to develop optimum expectancy or to recover from overestimated time intervals This implies that there is nothing necessarily unique about the expectancy phenomena that is not inherent in the slowdown with age

A fourth hypothesis, not discussed in the study, was offered by A T Welford (personal communication) He suggested that the increase with age in RT to the shortest or shorter PI's may be due to an age difference in the time spent in disengaging attention from the initial movement associated with the warning signal The curves in Figure 4 may be explained, therefore, by hypothesizing an age difference in the time required to become responsive to the auditory stimulus after involvement with this initial movement

To a certain extent, these four hypotheses are testable If RT's of two or more age groups are compared for both a regular and an irregular series, then, for the first hypothesis to be tenable (i e , age difference in time required to prepare or organize for response), the largest age differences would have to occur with the shortest intervals in both types of series An interval of 1 second, for example, would be equally inadequate in both regular and irregular series for the older subjects Simi

o

proximately the same for all PI's in an regular series in which, for example, the shortest interval is 4 seconds rather than 1 second All intervals are sufficiently long to permit adequate time for preparation However, this might not hold for very long

PI's because the problem then becomes one of maintaining set

[illegible]

for PI's presented in a regular series. This would exclude the notion of recovery or reorganization from inaccurate expectancies, since there would be neither systematic over- nor underestimation.

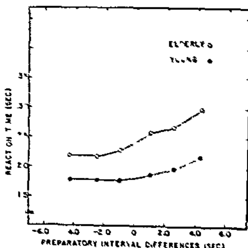
If the age differences in RT are the same for the various PI's in the regular series, then the fourth hypothesis would be excluded also. This hypothesis offers age differences in the time involved in initial movement as the reason for the increased age differences with the shorter intervals in the irregular series. The fourth hypothesis would be ruled out, of course, because there would not be increased age differences with the shorter PI's.

The third hypothesis offered to explain the data in Figures 4 and 5 was that the age difference in expectancy was but a reflection of a general slowing process. This hypothesis might be tested by the relation between level of RT and the slope of the expectancy function, as in Figure 4. That is, the hypothesis might be tested by the relation between quickness of over-all RT and degree to which short PI's make for relative slowness. If a steep slope, that is, relative slowness to short PI's, is related to a generally slow over-all RT, then slow individuals, old or young, should have steeper slopes than individuals who are fast regardless of their ages. Young slow subjects should manifest steeper slopes than older individuals who are faster. On the other hand, if the expectancy phenomena are related to the aging process independent of the general slowing, then the slopes of the older individuals who are faster should be steeper than the slopes of younger but slower individuals. This should hold for the functions plotted both as Figure 4 and as Figure 5.

Tentative results of one study not yet completed suggest that the second hypothesis may be tenable but that the first and fourth hypotheses are not. A couple of study (Brinley and Botwinick, 1959), however, suggests that with intervals less than 1 second, the first and fourth hypotheses may be tenable.

LOCUS OF EXPECTANCY

The problem of the primary locus of expectancy is controversial and has a long history. Without going into detail or exhausting the literature, it may simply be



1957)

indicated that Davis (1940), Freeman (1937, 1938), and Freeman and Kendall (1940) have provided data suggesting peripheral involvements, while Mowrer *et al.* (1940) and A. D. Weiss (personal communication) have provided data suggesting central involvements. Concern for this issue goes back to at least 1916, when Woodrow argued for a central locus (p. 291). Other pertinent and related references are by Freeman (1940) and by Huston *et al.* (1937).

Weiss was concerned with the problem of locus of expectancy and age. As subjects in two age groups performed in a reaction time experiment, muscle potentials were re-

corded from the extensor digitorum communis (forearm muscle to the index finger) of the responding hand It was thus possible to fractionate the total reaction time into premotor and motor time The premotor time was that period of time from onset of auditory stimulus to extensor activation Motor time was that duration from extensor activation to finger lift from the response switch When both motor time and premotor time were analyzed in relation to the PI as in Figure 6 the premotor time showed the characteristic relation while

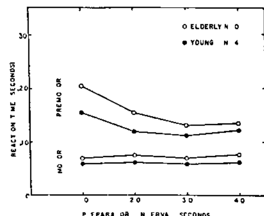


Fig 6 —Premotor and motor reaction time as a function of the preparatory interval for male subjects in two age groups 65–80 and 18–30 years (After Weiss personal communication)

the motor time was essentially a constant from one PI to another It appears therefore, that RT expectancy is localized premotorically

IV Expectancies (Long Term)

Definition

Activities in everyday living require continuous modification of prior experience such that some tendencies are inhibited and others maintained The susceptibility or proneness to certain behavior tendencies and the difficulty in surmounting or inhibiting them define long term expectancies Long term expectancies are differentiated from short term expectancies in that, with the former, the specific time relations tend to be longer than a matter of several seconds and, more important, are incidental to the contexts in which they occur The contexts of long term expectancies are of various sorts and include perceptual organizations, acquired habits, inhibitory processes, and cognitive abilities Although both long term and short term expectancies are developed in the course of experience and make for susceptibility to certain tendencies the respective underlying mechanisms may be different

Literature

With the exception of one study, the literature on aging in relation to problems of long term expectancy is very recent. This literature is a varied one, and, although still sparse it is growing rapidly The reader will find many of the following topics discussed in relation to the process of learning per se in chapter xix Emphasis here is in the ability to overcome differential expectancies or sets

Problem Solving Set

Heglin (1956, p 310) reported a study concerned with the relationship between age and 1) susceptibility to set, 2) ability to overcome set and 3) the relative effectiveness of attempts to train subjects to avoid set ' He compared three age groups of 50 male and 50 female subjects each with respect to these aspects of set or expectancy The ages of the three groups were 14–19 years, 20–49 years, and 50–55 years

Two types of related tasks were used one was a version of Luchin s water jar problems (1942), the other, a version of alphabet maze problems by Cowen *et al* (1953) These tasks induce a set that is appropriate at first, less appropriate in later problems because a shorter method is possible, and then inappropriate in still later problems because the method of the induced set does not solve the problems at all Following a series of such tasks, this

role of the induced set was explained to subjects as training to avoid it in a subsequent series Heglin found that with increased age there was increased susceptibility to set and difficulty in surmounting it Training benefited the 20–49 year group most and the older group least

REORGANIZATION OF PERCEPTIONS

Susceptibility to set or difficulty in surmounting its effects appears to be greater for elderly adults than for younger ones in perceptual behavior as well as in problem solving behavior Botwinick Robbin and Brinley (1959*a*) presented 74 male subjects divided equally into two age groups 19 34 years and 65–81 years with Borings (1930) amb guous figure of my wife and my mother in law (see Fig 7*A*) This figure is ambiguous in the sense that it can be seen either as a younger woman (wife) or as an older one (mother in law) After the percept of wife or mother in law was reported the subject was told that an alternate percept was possible If the subject was not able to reorganize the in tial percept and report the alternate one an unambiguous alternate figure was presented and the features po nted out when necessary (see Figs 7*B* and *C*) The subject was then presented with the ambiguous figure and asked what he now perceived The unambiguous figures were originally used by Carlson (1953)

The data suggested clearly that the elderly group held to the expectancies and did not reorganize the percepts as readily as did the younger group Several interpretations were used to explain these data but the one that is pertinent here is that the older group had more difficulty than the younger group in reorganizing the initial percept because of a general zed deficit in modifying or inhibiting ongoing tendencies

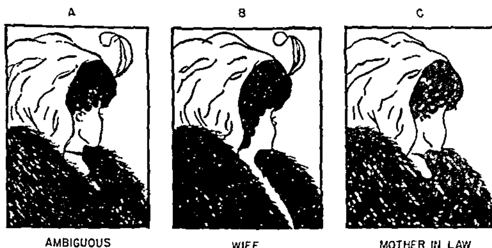


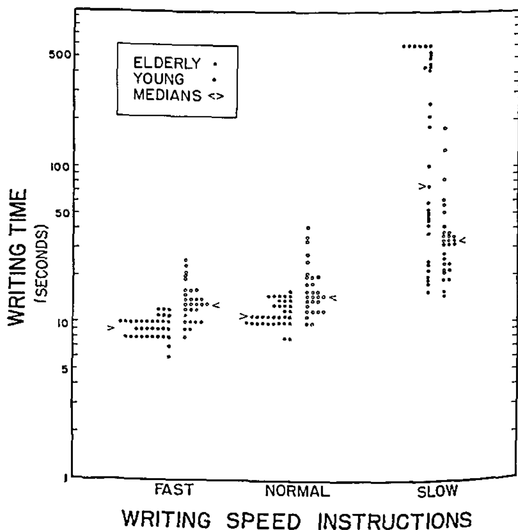
Fig 7—*A* ambiguous figure of my wife and my mother n law from Boring (1930) *B* and *C* unambiguous figures from Carlson (1953) (Data from Botwinick Robb n and Brinley 1959*a*)

MODULATION AND INHIBITION OF RESPONSE SPEEDS

An age deficit in surmounting the effects of an old set by modifying or inhibiting a well learned psychomotor skill was seen in a recent study Botwinick Brinley and Robbin (1959*b*) required 34 male subjects aged 18–32 years and 29 male subjects aged 65 81 years to inhibit normal performance by writing the phrase New Jersey Chamber of Commerce as slowly as possible This phrase was chosen because of its previous use in the literature and the fact that no letter *i* or *t* is used that would require dot

ting or crossing The time taken to perform this task was measured in seconds as was the time taken for normal and fast writings of the phrase

As may be seen in Figure 8, subjects in the elderly group did not inhibit writing speed to any large extent Their writing times for the usual fast and slow writings were not nearly as different as they were for the younger group These data suggested that older adults either cannot or do not inhibit response speeds as well as younger adults and thus do not control or surmount ongoing habits as readily When this diminution of inhibition of response speed with age is considered along with a loss of speed, and, as one study indicated a more constant rate of output (Botwinick and Shock, 1952), it appears that a general characteristic of aging is a constriction of range or modulation of response speeds It was suggested in the study by Botwinick, Brinley, and Robbin (1959*b*) that this constriction may have adaptive value



point of 600 seconds Scores are presented on a log scale (After Botwinick, Brinley, and Robbin

UNLEARNING

Susceptibility to set and difficulty in inhibiting its effects interfere with new learning because old learning has to be amended Kay (1951) suggested that, in a serial learning task, one response tended to form constraints and expectancies upon an other so that unlearning of the wrong re sponses in the sequence was required He found that older subjects were less efficient in the unlearning than were younger sub jects

Ten subjects in each of five decades from the twenties through the sixties were pre sented with a row of ten lights positioned above ten response keys Subjects were in structed that the ' correct ' key extinguishes the light and puts on another one The task was to find the serial relation of keys that extinguished the lights There were two series to be learned individually and then performed together by alternating from the first key of one series to that of the other, and then back to the second key of the first series to that of the second and so on As indicated, expectancy of sequential re lations needed to be reorganized and it was the elderly who found difficulty in this unlearning

REORGANIZATION OF PRE EXISTING HABITS

One of the oldest controlled studies in aging concerning reorganization of prior experience was by Ruch (1934) He admin istered motor and verbal tasks that called for surmounting or inhibiting set patterns of behavior

Ruch compared three age groups 12–17 years, 34–59 years, and 60–82 years with respect to tasks that required (1) extensive reorganization of pre existing habits (2) use of previously formed habits, and (3) neither reorganization nor aid of old hab its Using the motor tasks of direct vision rotor pursuit (old habit) and mirror vision rotor pursuit (reorganization), Ruch found the age deficits to be relatively largest in the mirror task for the oldest group This finding was substantiated indirectly by an experiment that required subjects to trace with a stylus usual and reversed mirror images of numerical figures on a metal plate Age differences increased with trac ing the mirror-image figures (Welford, 1951, pp 60–70) Similar results were found in unpublished data by the present writer wherein two age groups were compared in the relation between direct vision and mirror-vision tracing of a six pointed star

Ruch's verbal tasks involved paired as sociates (old habits), nonsense equations (new learning, neither old habits nor reor ganization required), and false products (reorganization) Age deficits increased in this order when the middle group was com pared to the oldest one but not when compared to the youngest one In a replication of the verbal material but with some pro cedural changes, Korchin and Basowitz (1956) found the age deficit to be about as large when a task involved new learning as when it involved the reorganization of pre existing experience They concluded that, with age, the primary deficit is in learning material which is novel

INTERFERENCE

Proneness to certain behavior tendencies and the ability to inhibit them are manifest in tasks that involve transfer and interfer ence By transfer is meant the effect, either positive or negative, that performance on one task has on performance on a second task In turn, performance on the second task may help or interfere with subsequent performance on the original task The latter type of interference is often called retroactive interference or retroactive inhibition or simply retroaction Negative transfer and retroactive interference thus involve proneness to tendencies that need to be surmounted or inhibited

Gladis and Braun (1958) studied trans fer and retroaction of verbal learning in three age groups of 40 subjects each 20–29, 40–49, and 60–72 years Other varia

ferences For example very few subjects over the age of 65 years are found free of arteriosclerosis If this condition is checked or remedied in the future then present random samples of elderly subjects will differ from future random samples of elderly subjects with respect to arteriosclerosis The more modified a condition becomes the larger will be the difference between present and future random samples of elderly subjects and the more will the differences between age groups diminish in time This diminution however may or may not be reflected in a similar diminution of age differences in variables that are related to the criterion variable

A HYPOTHESIS

In general the literature indicates that the behavior of elderly adults is more controlled by sets or expectancies than is the behavior of younger adults and that this control is involved in motor perceptual and mental abilities In this sense set is more of a determinant in the behavior of the elderly than in the young Elderly adults are benefited by this determinativeness if existing situations are compatible with the expectancies but hindered by them if the situations are not

It is possible however that this relationship is modified by one in which it is hypothesized that the increased number of life-experiences of the elderly involves an increased number of expectancies The increased number of expectancies may make any one particular expectancy less immediately determinant on a probability basis alone In addition if there are expectancies in competition with one another then one of relatively low strength loses effectiveness. If two competing expectancies are of equal strength then behavior oscillation and long response latencies may result.

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Another aspect of figure ground relation is the logical isolation of principles from their groupings In a different context, but perhaps testing a similar aspect of concept formation Welford (1951 pp 84–94) reported a study by Allan in which two age groups were compared with respect to the drawing of deductions from or pointing out fallacies in, a series of statements between which there were certain connections or inconsistencies It was found that the older subjects (mean = 49 years) tended not to draw logical deductions from the series statements but to supply additional premises or simply to confine themselves to comments about statements It was reported that the comments were items of information and opinions brought to the experimental situation from past experience The results were explained by both or either a loss with age in ability to organize complex material in a logical way and greater interference or intrusion with age due to increased experience These two explanations

[illegible]

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bles were investigated, but for present purposes these need not be considered Original learning (first task), interpolated learning (second task) and recall or relearning of original task declined with age No negative transfer was found, but the amount of positive transfer was largest for the youngest group With an analysis of covariance, no age differences were found in retroactive interference The analysis of covariance adjusted recall and relearning scores for differences in original and interpolated learning and vocabulary scores When recall scores were not adjusted for these differences, retroactive interference was found to increase with age

ALTERNATION

In a recent study elderly and younger subjects were compared in their ability to alternate or switch back and forth from one type of operation to a second type Alternating or switching fits the paradigm of expectancy in that it involves continual surmounting or inhibiting or response tendencies

Botwinick, Brinley, and Robbin (1958*c*) studied alternation of the arithmetic tasks of subtraction and addition The subjects that were compared were males in two age groups 39 were 65 81 years and 58 were 18–32 years In general, the method was to determine for each individual his rate of adding his rate of subtracting and his rate of alternating from adding to subtracting, back to adding and so on From his rate of alternating, rates of adding and subtracting were partialed out, leaving an index of alternation, independent to some degree of arithmetic ability

It was found by means of non parametric statistics that the two age groups differed significantly with respect to time taken to alternate The older group required more time to switch or alternate when arithmetic rate was partialed out

HABIT REVERSAL

In a study not yet completed, E A Jerome (personal communication) is observing Sprague Dawley rats in a series of problem solving tasks that are similar in some respects to problems of alternation or habit reversal The motivating technique that he is using is light aversion The data thus far indicate that rats aged 24 months and more show some deficit in switching or reversing habits as compared to rats aged 8–9 months

RELEARNING

A study in which no age deficit was found in surmounting the effects of prior experience was by Speakman (1954) This study was unique, since it took advantage of a life experience approximately 40 years long

The colors of some British postage stamps were redistributed in 1951 so that different values were represented This provided an opportunity to test for age differences in overcoming the old and currently inaccurate color value associations and establishing the new ones

In 1953, 67 subjects aged 20–86 years were presented with six stamps, each of a different color, and each with the number (values) punched out The subjects were divided into six age decades with 9–13 persons in each decade Contrary to the hypothesis of age deficit in relearning it was found that recall for the old values fell off with age and that recall for new values showed no consistent change

It is possible that the almost 2 years that intervened between the change in stamp colors and time of testing may be a factor related to these results In 2 years, perhaps, the effects of prior experience may be overcome by the elderly If the experiment were done 2 months after stamp changes rather than 2 years, different results would be possible

Another study in which no age deficit was found in modifying prior experience was by Botwinick, Robbin, and Brinley (1959*b*) Subjects sorted playing cards into six slots by matching sort and stimulus card numbers This was done with 71 cards for 8 successive trials After the 8 trials, 4

additional trials were given but with a changed order of stimulus card numbers Subjects in two age groups, 65–81 and 19–35 years, sorted more slowly with the task that was relearned The two age groups were similar, however, with respect to the extent of slowing

Theoretical Considerations

In this section the problem of expectancy is concluded with the consideration of an aspect of research design and sampling, a hypothetical formulation and an analogy to the brain damaged

RESEARCH DESIGN

A problem of research design may be considered by examining Gladis and Braun's study on interference (1958) When age groups were equated for original learning interpolated learning and vocabulary scores, age differences in interference effects were not found When however age groups were not equated in this way age differences in interference effects were found What specifically may be inferred from such data? Should age groups be equated? These questions are of basic importance, and their answers are neither obvious nor always agreed upon Related to these questions is one of sampling

Let us suppose that we wanted to repeat Gladis and Braun s study with samples of two age groups and that we had perfect random samples of an elderly and a younger group Let us also suppose that we found original learning scores lower for the older sample than for the younger If now we had a new sampling of elderly and younger subjects not randomly but with a criteria of original learning scores equal to those of the first sample of younger subjects, then we may expect to find a difference between the two samples of elderly subjects This difference might be *only* in original learning scores but more likely perhaps in other variables too It is possible that some of the variables separating both elderly samples would be intercorrelated to some degree For example, correlated with original learning might be variables of I Q unadjusted for age, education, health and *susceptibility to interference* effects (the very reason for which there is the experiment in the first place)

Which sample of elderly subjects should we use to test for age differences in interference effects? When Gladis and Braun adjusted their results for vocabulary and learning scores, their method was analogous to choosing the second sample of elderly subjects When they tested for age differences in interference effects prior to equating their method was analogous to choosing the first random sample Which method or sample to choose is to be determined by the purpose or problem of the particular study If the purpose or problem involves aging as it occurs in nature a clinical problem the choice is for the random sample If it involves aging of selected subjects a conceptual problem the choice is for the second sample If loss in learning ability is a primary result of aging and susceptibility to interference is a correlated and perhaps secondary effect, then clinically both effects must be dealt with concomitantly Conceptually, however the two effects can be separated as seen in the study by Gladis and Braun (1958)

At first consideration it might be thought that longitudinal research methods in aging studies would take care of this design or sampling problem However if age changes in original learning scores were found in a study on interference in a manner similar to the age difference scores in the random selection then the same statistical choice would need to be made That is in the longitudinal study where each subject acts as his younger control, a choice of adjusting or not adjusting for original learning that may change with age would need to be made in testing for susceptibility to interference effects

There is one further aspect to this design problem The variables upon which age groups are equated or the criteria of subject selection, may be modified in future time and may alter the picture of age dif-

ferences For example very few subjects over the age of 65 years are found free of arteriosclerosis If this condition is checked or remedied in the future, then present random samples of elderly subjects will differ from future random samples of elderly subjects with respect to arteriosclerosis The more modified a condition becomes the larger will be the difference between present and future random samples of elderly subjects and the more will the differences between age groups diminish in time This diminution however may or may not be reflected in a similar diminution of age differences in variables that are related to the criterion variable

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In discussing age differences in ability to articulate a percept into figure and ground and in logical abstraction the major emphasis has been on the intrusion of experience and thus on the determinativeness of behavior due to an expectancy of one form or another There is another interpretation of such data that has been made in the study of brain damaged patients Werner and Strauss (1941), for example, reported that the brain damaged are at the mercy of outside forces' in that they cannot concentrate only on task relevant stimuli They

are unable to withstand the attraction of stimuli which may be extraneous to the task at hand This would explain inability to separate figure from ground if the ground contained the attracting stimuli or to explain the deficit in logical thinking because of the compelling aspects of the irrelevant material

At first consideration it might appear as if these were two unrelated interpretations of the respective deficits The interpretation related to aging emphasizes intrusion of set and the interpretation of the brain damaged emphasizes the compelling attraction of irrelevant stimuli The latter interpretation does not mention prior experience These two interpretations however may be thought of as parts of a more inclusive theory It may be considered that irrelevant stimuli are compelling because they elicit a chain of sets or effects of prior experiences which intrude in the successful solution of a task Birren (1955*b*) reported a study in which subjects were required to free associate words beginning with specified letters Senile hospital patients performed poorly and their lists beginning with the letter *s*

> might contain *swim water cloud rain* etc as though each word served as a stimulus for the next leading the subject astray from the task Attempts to correct such performances gave the impression that these patients were lacking the ability to inhibit the logically associated words i e the associations were stronger and had priority over the task set [1955*b* p 244]

In the context of the two interpretations it is hypothesized that stimuli relevant or irrelevant are compelling in their elicitation of a chain of internal events and that brain damaged patients and elderly adults especially senile hospital patients are less able to inhibit or exclude sets inappropriate to the task at hand

It is to be emphasized that if there are behavioral similarities between aged individuals and brain damaged patients and if the same or similar theories or models are useful in both types of investigations it is not to be assumed that aged brains are damaged or have lesions All that may be said is that there is an analogy and that the analogy may have biological similarities or not

V Emotions

Definition

Under the rubric emotion problems have been studied that range from subjective and fleeting mood states to relatively permanent and deep seated pathological conditions The antecedents of these problems have included events in the history of the organism transitive stimuli social and cultural organizations and anticipatory events The complexity and diversity of problems that are studied as emotion may be seen for example in a published account of a symposium edited by Reymert (1950) It is clear that the study of emotion must include other processes such as perception or learning and must take into consideration specific situations If with age there is decline in biological function resulting in performance deficits then there may be loss in self reliance and depending upon the specific situation a loss in ability to obtain rewards The rewards may be social approval or any other circumstance that relates to feelings and emotions about the self

Emotion in this chapter is defined as an internal event of the organism measurable by bodily changes and by behavioral changes but no necessary instrumental or consummatory response is presumed to be present As with the construct drive, or with any intervening variable for that matter the inference of emotion and its extent is more reliable when antecedent conditions are known An introductory statement by Lindsley is pertinent

> In general the topic of emotion has been approached via two principal aspects the experiential or feeling aspect and the expressive or behavioral aspect The former has been studied by introspective methods the latter by way of inferences based upon observed behavior Both

procedures are notably unreliable and both have led to highly speculative theories of emotion Nevertheless such basic data as there are on emotion have come largely through the study of its expressive aspects and objectively recorded bodily changes [1951 p 473]

Some of the work discussed in this section on emotion could have been placed under the headings of long term expectancy or drive and indeed some of the work in these sections is similar It is not surprising that a clear distinction between drive, expectancy and emotion is not always available, since all are inferred constructs which have determining properties In general this section on emotions more than previous sections tends to be concerned with the problem of bodily change or psychophysiological response and with literature of aging processes explained by reference to constructs of personality theory Discussions of specific personality theory systems are not included here, however, since in another chapter this is dealt with in detail (see Riegel, chap xxiii) Similarly, the effects of persistent and long term psychophysiological arousal as expressed in psychopathological conditions are not treated here but are discussed in chapter xii by Busse

Theoretical Considerations

Problems of inferring age changes in emotional states are concerned with both input and output The problems are more difficult, perhaps, with measures of output Lindsley (1951) discussed more than fifteen different psychophysiological indexes of emotion, and, while the literature on aging is concerned with these indexes, the concern is not in the context of emotion This is not surprising since age differences in these indexes are so often indicative of pathology that the problem of what is normal aging and what is disease in senescence become the crucial one Therefore, when there is an age difference in a measure of emotion, as for instance, a change in blood pressure, or galvanic skin response (GSR), electroencephalogram (EEG), etc, in relation to a change in the environment, it is difficult to determine the appropriate base line from which psychophysiological change may be evaluated In the study of emotion this difficult problem may be overcome methodologically to some exent if the measurement of change is in terms of frequency or simply of whether there was or was not a change of response to a change in environment. For example, GSR's may change with stimulation, and all that may be recorded is existence of change rather than magnitude of change Such information may be valuable but probably not to the same extent as continuous data Continuous data could be obtained profitably when the age differences in base line data are not excessively large or are without complications of pathology

On the input side the problem of inferring age changes in emotional states is related to the one of the definition of the stimulus or meaning of stimulus change. Is an age difference in the sensing or perceiving of an emotional stimulus a basis for utilizing differential stimulus conditions in an experiment? If, for example, as was the case in one study (Botwinick, Brinley, and Robbin, 1958*a*), subjects in two age groups are induced to respond more quickly than usual by the use of shock motivation, are there to be different intensities of voltage or current for each age group in order to equate for sensation or perception? If so, how is the intensity determined? If it is determined by the response, we are equating age groups for the very thing we want to measure If it is determined by outside criteria, then we may be assuming a relationship that does not exist On the other hand, failure to equate age groups on the basis of input may lead to spurious conclusions One way out of the dilemma, perhaps, is to use two conditions in the experiment one is to equate, and the other is not to equate, age groups for input A simpler method is to use stimulus intensities sufficiently high to make for effects that are likely to be

maximal for all age groups This has the possible disadvantage, however, of mini mizing age differences that would be maximal with low intensity inputs

In view of the problems inherent in the measurement of age changes in emotion by psychophysiological means more gain may be made at the present time with measure ment via task, psychometric, or problem solving performance This gain, however may be only apparent As more is learned of basic behavioral age changes, difficulties might arise in addition to the problem of pathology Age changes in specific capaci ties and abilities may be found to interact with age changes in emotion to such an extent that it would be impossible to sep arate them

Possible interaction among age, capacity or ability, and emotion presents interesting conceptual problems as well as methodo logical ones If an elderly man when driv ing his car is slow, this may be because he is careful, or, if he is careful, it may be be cause he is slow to react Similarly he may be anxious because he is unable to perform or he may be unable to perform because he is anxious It may be of course, that the reason for the particular type of perform ance is that he is both slow and careful or unable and anxious These considerations are also of practical importance For ex ample, if the primary defect is anxiety, then its reduction should improve perform ance If the primary deficit is capacity then, to improve performance, more time might be spent profitably in altering task or environmental variables than in psycho therapy Theoretically the problems are What are the primary age changes? What are the secondary ones? It may be that capacity and anxiety are both primary In this case, the question is Which contrib utes more to total variance? The answer to this question, or the viewpoint one takes, determines in large measure the interpre tation that one imparts to data To illus t ate in the study by Botwinick Robbin, and Brinley (1959a), in which elderly and younger subjects were compared with respect to responses to Boring's ambiguous figure (see Fig 7A), the results were interpreted in terms of perceptual deficit or the loss with age in ability to reorganize perceptions In two recent studies that are similar in several respects to this one, data were interpreted in terms of ego organiza tion (Korchin and Basowitz, 1956) and ei ther cautiousness, integrative ability, or both (Basowitz and Korchin, 1957)

Literature

From the foregoing it may be anticipated that the literature on age changes in emo tion is amorphous and difficult to classify and even to distinguish from other litera ture not designated as concerned with emo tion The decision to classify a study as concerned with emotion rather than expect ancy or drive was based largely, as indi cated previously on the general theoretical frame of reference of the study Other de cisions would probably be equally good or bad

EGO ORGANIZATION

Korchin and Basowitz (1956) investi gated age differences in decision making as it may be related to personality organiza tion They used a young group of subjects comprising 12 resident physicians and 12 graduate nurses This group ranged in age from 22 to 33 years with an approximate mean of 27 years Nurses and physicians were of about the same age This young group was compared to elderly subjects who were residents in a home for the aged and in apparent good health This second group comprised 36 persons half of whom were male and half female Six male and 6 fe male subjects were in three subgroups 65–74, 75 84, and 85 and above years

Each subject was administered a proce dure that was similar to one first reported by Frenkel Brunswik (1949, p 128) to assess 'intolerance of ambiguity' The procedure that Korchin and Basowitz used involved thirteen line drawings, the first of which was a cat which by successive modi fications became a dog The most ambig-

uous drawing, the one that was both least cat and least dog was the seventh drawing Each drawing was presented tachistoscopically, and response time and the decision of 'cat' or "dog was recorded for each person tested individually In general, it was found that younger subjects changed from "cat to 'dog' near the center of the series and continued with that response The older subjects tended to vacillate more and shift back to the response 'cat" The point of final shift from "cat" to "dog" was later in the elderly group It was suggested that these results might be equivalent to age differences in perseveration

Response latency increased from young to elderly groups and from the youngest to oldest subgroups within the elderly sample The difference in response time between the ambiguous stimuli and unambiguous stimuli was found to be larger in the younger group than in the elderly group However, this difference appeared to be larger between nurses and physicians of the same age than between age groups Korchin and Basowitz (1956 p 94) interpreted their data as a reflection of "less adequate ego organization of older *Ss* They are less capable of establishing and maintaining an appropriate differentiation of the phenomenal field and are, at the same time, more susceptible to the novelty and potential threat in the total situation"

The antecedents of ego organization and, therefore, behavior that is related are most often considered to exist in the personal and social life history of the individual However, the antecedents may also lie in the biological capacities of the individual For many purposes this distinction is unnecessarily dichotomous, but, as already indicated, there is a practical reason for considering it If the ego becomes restricted with age and if this restriction is related primarily to biological factors, then what is recommended or done to relieve behavioral disability may be quite different from what is done if ego restriction is due to personality and social factors While this distinction is important, it should not be forgotten that descriptions of age differences in behavior are prior to the interpretations that are made from them The basic data of Korchin and Basowitz indicate a type of clinical rigidity and perseveration that by itself does not imply any one antecedent condition

CAUTIOUSNESS AND INTEGRATIVE ABILITY

In a study by Basowitz and Korchin (1957), two age groups were compared with respect to performance on two tasks adapted by Thurstone (1944). One task was Gestalt completion in which portions of drawings are obliterated and need to be supplied perceptually by the responder The other task—concealed figures—involves finding a simple geometric figure in a complex design The two age groups were 22–33 years (mean, 26 8) and 68–88 years (mean, 78 1) The younger group comprised 5 men and 11 women (doctors and nurses), and the older group comprised 8 men and 18 women who were residents in a home for the aged

The young group performed more adequately than the elderly one both in Gestalt completion and in perceiving concealed figures With Gestalt completion, the young group omitted fewer items and perceived more drawings correctly and fewer drawings incorrectly With the concealed figures, the young group again completed more items than the elderly Performance of the younger group was also more adequate when only those items completed were considered

These data were interpreted as indicative of a change with age in

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> cautiousness, i e, a defensive reluc[illegible] venture response for fear of recognizing their inadequacy The overall results were viewed as reflecting the overly loose or overly rigid cognitive functioning of the aged [Basowitz and Korchin, 1957, p 96]

The decline with age in ability to do Gestalt completions and to find concealed

figures can be explained in an additional way It may be that, as a result of diminished sensory and perceptual capacity, there is a reduction of the number of cues that are extracted from the test material Thus, as Basowitz and Korchin suggest, there may be lessened integrative ability, but, in addition, there may be less information available to integrate

RESPONSE REVIEWING

A concept that is similar to cautiousness, perhaps, is response reviewing It was suggested in a study by Botwinick Brinley, and Robbin (1958*b*) that with age there may be an increase in ' response reviewing or confidence level required before responding " Two age groups were compared in both speed and accuracy of judging which of two vertical lines, presented simultaneously, was the shorter The line pairs were presented tachistoscopically under two conditions of exposure duration 2 00 seconds and 0 15 second The line pairs were varied systematically in difficulty within each condition of exposure duration Difficulty was defined by the difference in length between line pairs, the less the difference the greater the difficulty

The younger group comprised 26 subjects aged 18–35 years (median, 22 5) and the older group comprised 34 subjects aged 65–79 years (median 71 0) All subjects were community residents except 3 older subjects who were residents in a home

The results were that as the stimulus judgments became more difficult the older group became *relatively* more slow The effect of the decreased stimulus exposure time was to reduce in the elderly group this *relative* increase in response latency with the difficult stimulus material With respect to accuracy of response there was a distinct advantage in favor of the young group However this advantage appeared to be independent of stimulus difficulty or duration These results were interpreted 'as if the older person takes a longer time with the difficult discriminations when he has this time to take, but relative to his ability to discriminate correctly, the older person may not require this added time " The implication is that the time used may have been for response reviewing if a higher confidence level was required before responding

The explanation of these results is not incompatible with a formulation of aging that relates increased accuracy to failing speed Welford (1951, p 66) reported that when subjects in six age groups were required to trace figures ' the subjects in their thirties appeared to maintain the speed of those in their twenties but at the expense of accuracy From the forties onwards accuracy was restored at the expense of speed "

Whether a tendency toward accuracy with advancing age is a consequence of loss of speed or whether it is due to changing values or motivations is a question that needs to be answered The *consequence hypothesis* suggests that the slowdown with age is primary enabling constant review and indirectly greater accuracy The *changing motivation hypothesis* implies that there is purposeful slowdown with age in order to obtain accuracy either because of an increased value on carefulness or because of increased tendencies to make errors Both hypotheses may be tenable and may apply at the same time Nevertheless what may be interpreted as purposeful slowdown with age does not always succeed in making for accuracy superior to that of the young (Botwinick, Brinley, and Robbin 1958*b*) and what age differences in motivation may exist do not necessarily explain general slowing as is seen in the next study described

MOTIVATION

Botwinick, Brinley, and Robbin (1958*a*) were concerned with the problem of motivation in the elderly The problem of motivation is complicated and is as frequently viewed as a drive variable as one of emotion It is considered here under emotion,

however because in this chapter the concept underlying drive was that of control being exerted *on* the individual while the study on motivation had as its underlying concept that control is exerted *by* the individual Kay (1955 pp 265–67) discussed this problem very adequately in a different context He considered the problem of whether with elderly persons a change in motivation affects learning ability (control exerted *by* the individual) or whether a change in learning ability affects motivation (control exerted *on* the individual) In any case the distinction between emotion and drive is made once again on the basis of theoretical orientation rather than on the nature of the data

Botwinick Brinley and Robbin (1958*a*) investigated the role of motivation in the increase of response time of the elderly They argued that if the reason for the slowdown with age was decreased motivation to respond quickly then increased motivation induced experimentally in a young and in an elderly group should result in disproportionate larger decreases in reaction time of the older group

Sixty male volunteer subjects divided equally into two age groups were tested individually by a series of 24 simple reaction times to an auditory stimulus The age range of the younger group was 18–37 years (median 23 5) and the range of the older group was 65–79 years (median 71 0) Most of the elderly subjects and many of the younger subjects were the same ones tested in the study on judgments of line difference

Following the series of 24 reaction time measurements the median for each subject was computed There followed a second series of 24 measurements but with instructions to the subject carried out in the experiment that a mild shock would be administered to the wrist for responses slower than his own median reaction time

Results were that reaction times were decreased in both age groups with the increased motivation of shock The decrease in reaction time, however, was about the same for both age groups, suggesting that initial level of motivation does not appear to be the explanation for the loss of speed with age As may be seen, in this type of study practice effects may interact with motivation effects Analysis of previous data (Birren and Botwinick, 1955), however, indicated that practice effects would probably not be appreciable

There are recent data, however, that cast doubt on the generality of the conclusion that was reached with regard to motivation and age (Botwinick, Brinley, and Robbin, 1959*a*) The data include non shock and shock motivated reaction times of two age groups under three conditions of certainty One condition—for all practical purposes a repeat of the original study—involved irregular preparatory intervals ranging from 1 to 6 seconds Another condition involved intervals that ranged from 1 to 25 seconds (least certainty), and a third condition involved intervals presented in regular series (most certainty) Like the results of the initial study (Botwinick, Brinley, and Robbin 1958*a*), extent of decrease in reaction time with shock motivation was the same for old and young with both irregular series Unlike the results of the initial study however, improvement with shock was greater for the older than the younger subjects when the series of preparatory intervals was regular It appears therefore that it is necessary to consider the particular situation (at least with respect to the certainty of the time that an environmental event will occur) before the role of motivation in aging processes can be assessed

VI Summary

This chapter was concerned with changes in general responsiveness that occur with age The disposition or readiness of the elderly to respond to stimulation was considered in terms of drives, short term expectancies long term expectancies and emotions It was suggested that the comparative study of the limits of plasticity of behavior of aging organisms would aid in

the evaluation and development of procedures that maximize productive output of the elderly

Whether the effect of age on drives, expectancies, and emotions should have been discussed as age differences or age changes depends upon what is currently judged about the influence of culture or society More information would make judgments more reliable and valid For the purpose of clarity, however, convention was adhered to in this chapter by describing age differences or changes in terms of method

Drives

Drives were discussed as constructs representing internal events of the organism leading to behaviors that may satiate states of physiological deprivation or arousal Problems of research planning were considered that had to do with assessing and equating age groups for amount of drive underlying physiological processes and of determining and satiating characteristics of behavior

Studies on the influence of age on the drives of hunger, sex, activity, and light aversion were described In general, hunger drive of 1 day was similar for male albino rats in two age groups 150–75 days and 300–350 days With increased hunger deprivation to 3 and 5 days the younger group increased drive proportionately more than did the older group

Sex potency was found to decrease with age in human males but not in females Male albino rats also showed signs of sexual aging

Spontaneous activity in the rat appears to increase from birth to puberty and then decline No age difference was found in light aversion for rats approximately 1 and 2 years old

The results of these studies were discussed in connection with influence from the environment and from alterations in internal events as they relate to age

Expectancies (Short Term)

Expectancies to respond within short intervals of time have been studied in reaction time experiments The better or more adequate the state of expectancy, the shorter or quicker the reaction time An experiment was described in which male subjects in two age groups were compared statistically with respect to the relation between reaction time and the preparatory interval It was found that the older group was relatively slower than the younger group with short preparatory intervals than with long intervals That is, the older group was at a relative disadvantage when little time was permitted for preparation Four hypotheses were offered to explain these results and experiments were suggested to test the hypotheses The four hypotheses, not necessarily mutually exclusive, are that in the course of aging more time is required to develop a state of optimum expectancy, more time is required to overcome the effects of inaccurate expectancies, there is a general slowing process that involves expectancy phenomena as well as others, and there is an increase in the time required to disengage attention from prior movement

Expectancies (Long Term)

The susceptibility to certain behavior tendencies and the difficulty in surmounting or inhibiting them define long term expectancies Specific studies concerned with the relation between expectancy and age were described These studies concerned problem solving set reorganization of perceptions modulation and inhibition of response speeds, unlearning, reorganization of preexisting habits interference, alternation, habit reversal, and relearning All but two studies pointed to an age deficit in expectancy functions Problems of research design and sampling were discussed in relation to this age deficit, and a hypothetical formulation and an analogy to a theory of human brain damage were offered

Emotions

Emotion was defined as an internal event of the organism measurable by changes in both bodily reactions and behavior It was indicated that a clear distinction among drive expectancy, and emotion is not always possible, since all are inferred constructs and have determining properties In general emotions were differentiated from drives and expectancies by an emphasis on literature of psychophysiological response and of aging processes that were explained by reference to constructs of personality theory

It was said that age changes in emotional states are difficult to assess While emotion is often measured by changes in bodily reactions to changes in the environment, there are age changes in bodily reactions independent of changes in environment The questions needing answers are what is normal aging and what is disease in senescence

The assessment of emotions in aging from behavior studies may be equally difficult A problem that has both theoretical and practical significance is involved with the interaction among age, capacity or ability, and emotion One illustration of this problem is whether in driving a car, elderly adults are slower because they are more careful or whether they are more careful because they are slower to react

The different studies that were reviewed suggested similar age changes One study concluded there was less adequate ego organization and greater susceptibility to novelty and potential threat Another study indicated a carefulness with age or a defensive reluctance to venture response for fear of recognizing inadequacy A third study emphasized a greater tendency with age to response reviewing or confidence required before responding A fourth study was concerned with motivation No age difference in motivation was found with respect to speed of response It was indicated, however, that there are age changes in motivation to respond quickly in different types of situations

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XXII

The Use of Time and Energy

JOHN E ANDERSON

I Introduction

In this chapter we consider the way in which the human being organizes and spends his energy in his own world of time and space There are two major areas The first refers to the organization of the specific units of behavior by means of which he meets the particular situations which confront him This is the problem of the content of his behavior Much of psychology treats of the manner in which specific patterns of action are learned The other is concerned with the manner in which the person selects and arranges his activities in time and space so that his time becomes occupied Sometimes this is termed the problem of motivation or why the person does what he does sometimes the problem of interests or the direction of energy into channels which involve one content rather than another and sometimes the problem of activities or the way in which the person actually fills the time he has available In any event we are talking about play about work about leisure activities about what the person does not so much in terms of this or that particular activity but in terms of the interrelation of activities This is an area in which despite our frequent statements about the lowered energy and the diminished activity of older people we have relatively little information we know much more about the content of particular behavior systems in older persons than we do about the interrelation of behavior systems

Nevertheless it is clear that there are changes and that over time some some activities move toward stabilization and incorporation into the whole pattern of living while others are eliminated Two relations are clear however as we view the human organism over time First he is *multipotential* in that his behavior can be organized in any one of many different directions with regard both to the content and to the energy devoted to them second he lives in a world of time and space which sets limits to what he can and cannot do and thus forces *selection* The basic fact is that the person lives in a world in which a day has only 24 hours and that his environment is so rich even when it is somewhat limited in the ordinary sense that he can not do everything he wishes to do nor can he develop all his potentialities to the full The selection which results is partly deliberate but much of it takes place without deliberation because of the demands of the environment the necessity of living with one s fellows and the fact that in a modern society the roles of individuals and of functions are clearly delimited

It should be pointed out that we gradually adapt the growing child to the demands of our society and produce a person with developed skills who as an adult can meet the demands of life in our society A major demand is that he become a producer in order to live in our work-oriented and money oriented society and that after he reaches maturity, he maintain his place

as a responsible citizen until the age of 65 years or thereabouts Then we suddenly re lease him from the work and money ori ented demands of the adult life to which he is accustomed and expect him to develop activity patterns on a self initiated basis But we have meanwhile taken out many of the primary and secondary motivations that have carried him along Hence the problem of the use of time and of energy and of motivating older persons becomes of major import While we know something about the content of particular traits and skills and about their acquisition in older people we know much less about the prob lems of motivation of time filling and of organiz ng patterns of activities To a somewhat greater degree than is true of the other chapters in this *Handbook* we have to make inferences from a variety of stud ies that furnish leads rather than being able to point to studies done in a similar way over a wide range of ages which reveal basic trends But this deficiency in our knowledge is not limited to the field of ag ing Generally speaking at all age levels we know less about the selection of activi ties and the motivation of behavior than about the content of the resulting behavior

II THE HUMAN BEING AS AN ENERGY SYSTEM

By nature the human being is active rather than passive In common with most

o

of need or need arises out of mobility it is quite clear that in the evolutionary proc- ess the sense organs and the nervous sys tem appeared as the devices by means of which the energy developed within the or ganism is channeled and directed to par ticular outcomes in behavior

The sense organs and nervous system act as releasers of the energy requ red to effect the major bodily actions which involve great amounts of energy The specific stim uli are superimposed upon a basic pattern of internal activity, and as Hebb (1955) points out a living organism is more like a steam engine with a head of steam main tained by an internal process than like a machine such as an automobile engine which starts or stops completely by turn ing a switch

The human being or any living system may be regarded as an energy system in the sense that it takes in fuel and converts it into work But it is not a closed system such as a machine that runs down or burns itself out by activity it is rather an open system that maintains a fairly constant level of energy transformation (Freeman 1948) by continuous replenishment plus substantial capacity for self repair When

h al down this unified living system

lar activity that produces changes external world In order to carry on this activity great amounts of food must be taken in and if the activity level is in creased the intake must also be increased or the system will deteriorate But in ad dition a substantial amount of work is also done within the living system itself in or der to maintain itself and its parts and sub- systems at a homeostatic level In the young organism additional food is trans

n h Under some condi

ly increase the rate of energy exp for a time with return to a normal level after the emergency has passed (Cannon 1929) In addition there is a higher *level* of activity maintained during the waking hours which is followed by a lessened ex penditure of energy during the recuperative period known as sleep So much for a sketchy outline of the physicochemical plant consisting of the digestive and elimi native system the respiratory and circula tory system and the muscular system which build up and maintain the large amount of power that is available with n the living system

But coupled with this major power sys

tem, which converts food into energy and waste products, there is a control system which consists of the sense organs and the nervous sytem These operate on a very small amount of energy diverted from the major source of power in order to control and direct it Although there are, at the minimum, two coupled systems, this is an oversimplification of what is in fact a much more complex interrelation of systems In this paper we cannot go into the details of coupling or of subsystems within the major power system or the control system Coupling is a problem faced in the design of every machine which transforms minute amounts of input or stimulation into enormous expenditures of power In the modern science of cybernetics there is a detailed discussion of the principles of coupling and of the relations of control systems to power amplification both in living organisms and in designed machines (Ashby, 1954, 1956)

If we regard the living system as an energy system and ask questions about the relation of activity to the well being of the system, particularly in the light of its capacity for self maintenance and self repair, provided input is kept up, it follows that use and activity are beneficial to the person and that the normal healthy person is essentially energetic and active When the person becomes ill, or has inadequate nutrition, his activity level drops in order to conserve his resources Non activity and non use in the long run result in deterioration Even methods of treatment which involve immobility for long periods may be more harmful than the defects and illness that are being treated Modern investigations in many fields have radically changed our conceptions of what activity does for the health and well being of the organism

Input and Behavior

That there is a relation between the over all amount of stimulation received by the organism and its activity level is suggested by recent studies which give us a flow concept of behavior Attention should go to the recent work of Hebb (1955 and 1958) and his associates and to Heron (1957), who restricted the amount of stimulation received by humans and animals to minimal levels and found that behavior and activity quickly deteriorated They believe that a certain massive amount of arousal stimulation is necessary to keep the organism functioning and that, above this stimulation level, there is the cue stimulation which enables us to perceive objects and relations and build specific responses Thus there is a kind of psychological tonus, not too different from the concept of physiological tonus, which is maintained by arousal stimuli When these drop below a certain level, all activities are affected

Ordinarily, we think of a person in terms of specific responses and often go so far as to think of a stimulus as occurring only once and then producing an action But when observations of children in their habitats were made by Barker and Wright (1955), by following children around and recording their behavior from early morning until late at night, a different picture is obtained In their analysis they found some 2030 different settings made up of behavior objects in which behavior occurred and to which children were called upon to react By sampling techniques they estimated the total number of behavior objects to which the normal 8 year old child can react and came out with a figure of 1 200 000 This figure should give us some pause as it indicates the tremendous number of differential responses which the child has already built out of his high intake and high outgo at a comparatively early age Moreover Barker and Wright find that some 2200 distinct transactions involving some 660 different situations occur during a waking day Many of these are outside the formal school situation Furthermore, experience has a marked repetitive quality when observed from day to day Children are not told to do a thing once and then proceed to do it, rather they arrive at organized behavior through iteration and re-

iteration—in other words, through time and practice

Studies such as these reveal the high input and high outgo, or the flow of stimulation and response, in which single elements or moments of time are of relatively minor importance in comparison with the direction of the flow of experience and activity

Activity and Age

Some years ago many studies of the activity of animals were undertaken in order to determine the effect of various factors on their spontaneous activity In the main, these studies were done on white rats and

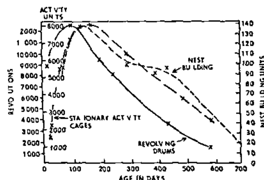


Fig 1—Age and activity in the white rat (After Richter 1922–23)

used revolving cages or activity cages of various types All these cages used automatic recording devices It should be noted that cages are restricted environments when compared with natural ones Among the many factors studied was that of chronological age The first experiments by Slonaker (1907, 1912) found that spontaneous activity increased during the first third of life and then decreased until death Unexercised controls in ordinary cages lived longer, were heavier, and were less alert than animals in activity cages Richter (1922–23) drew up age activity curves based on 5–8 day records at six different age levels His curves for three separate measures of activity are reproduced in Figure 1 Richter reports 100 days as the age of greatest activity and finds the 240 day-old rat less active than the 30 day old rat

Shirley (1928) found that male rats maintained a high level of activity from 5 to 9 months, after which activity declined to the age of 14 months, when she terminated the runs What was even more interesting was her finding of much inconsistency in the activity patterns of the younger animals from month to month But after the age of 6 months each rat maintained its place in the group quite consistently The correlation coefficients at successive months rose until the coefficients reached the order of 80 in the adult rat

Anderson and Smith (1932), in a study of age, nutrition, and performance, compared rats who were qualitatively stunted (by means of a diet in which gliadin was substituted for casein) and rats who were quantitatively stunted (by reducing the total calories) with normal rats at the same ages In this experiment the rats were fed measured amounts of food Normal animals at 31 days showed the greatest amount of activity followed by a steady decrease until 151 days, when observations terminated Although the qualitatively and quantitatively stunted animals showed much greater activity throughout than did the normal animals, they too showed a decrease in age in their activity with age This decrease was more marked in the animals on the qualitatively deficient diet than in those on the quantitatively deficient diet This suggests that age changes take place not only within normally fed animals but also within animals on markedly de-

at 31 days and found that, when tested at 144 days after realimentation, the activity level of all groups was very close to that obtained at 151 days on a normal diet on a previously tested group selected from the same litters

In a recent study Jones *et al* (1953) studied the relation between activity and age and the length of time the animals had been in a wheel cage They found a marked relationship to age as shown in Figure 3

of chapter xxi (Botwinick) Initial activity markedly decreased with age Then at all age levels activity increased with experience in the work cage Although older animals took a shorter time to reach their maximum activity level and maintained that level more effectively the age differences were even more striking at the end of the training period than at the beginning

In summarizing these studies it is clear that they all agree in finding a decrease with age in spontaneous activity in the white rat Different studies place the period of maximal activity at different younger ages

With regard to the relation between spontaneous activity and age in the human we have little data because of the difficulty of separating the natural activity pattern from the superimposed controls on activity that are set by living in society Most of us who have had children have been amazed at their activity level and those with grandchildren even more so Some evidence has been brought together by Brody

more rapid rate The older person possesses specialized activities adapted to the demands of the situations presented He meets these demands by directing his energy rather than by an intense display of energy

Because of the relation between food intake and the amount of work done it is usually assumed that as activity or physical work done decreases the food intake should be lowered In the growing organism some of the food intake goes to maintenance some to activity and some to growth in the adult when growth has stopped intake goes to maintenance and to activities above the maintenance level In the older person less intake is necessary because the maintenance level is lowered and because the activities above the main tenance level are reduced

An excellent summary statement with regard to food requirements was recently issued by the Nutrition Division of the Food and Agriculture Organization of the United Nations (1958) from which the following quotation is made

> Studies on the food consumption of elderly people have shown that their calorie intake is substantially smaller than that of young adults As people become older they tend to engage in employment requiring less energy expenditure and to cut down physical exercise in non occupational activities accordingly they need less food There is however evidence that where food is available in abundance the food intake is not always reduced in accordance with reduced energy expenditure
>
> Skill may reduce the energy requirements for a specific task In general it may be said that an older man finds it hard to acquire new skills but maintains old skills well The effects of changes in skill and in muscular efficiency with aging on the energy cost of industrial operations are as yet not well known The tendency for expenditure of energy to decrease uniformly from the age of 5 onwards is real but it may of course be materially affected by the necessity of earning a livelihood and by the demands of social custom
>
> Another point is that the basal metabolic rate decreases steadily after the early twenties In men the decrease is practically a linear function of age and at 65 years the B M R is about 20 percent less than at 25 In women up to the age of 45 or thereabouts the decline in the B M R is somewhat less rapid

The adjustment for age recommended by the Nutrition Division is as follows

	Per Cent
For the decade between 25 and 35 years subtract	3
For the decade between 35 and 45 years subtract	3
For the decade between 45 and 55 years subtract	7 5
For the decade between 55 and 65 years subtract	7 5
For each decade after 65 years subtract	10 0

III Stabilization Time filling and the Ordering of Behavior

In the Shirley study of activity in the rat the intercorrelations between patterns of activity in the young animal are very

low, whereas those for the older animal are very high This suggests that, as the organism ages it stabilizes its activity patterns and expends energy consistently in relation to time and space Such stabilization resembles the aging phenomena observed in perception, namely the progressive appearance of constancy, which enables us to code and classify our input For motor skills age and learning produce a *progressive simplification of behavior* All these tendencies can be grouped under the general heading of "structuring" Even under conditions of great freedom the tendency toward the structuring of behavior appears Consider the appetites which appear as needs and are followed by behavior *which reduces the tension or satiates the* appetite But after a time tension builds up, and the appetite must be satisfied again This cyclical model holds for such phenomena as thirst, hunger sleep sex and perhaps other systems But in infancy and childhood there is superimposed upon ap*petites a process* which *we call* "scheduling" In their earliest appearances the demands of appetite seem almost random with respect to the time of day but after some weeks or months demand is confined to particular periods and a predictable schedule with consistency emerges A study by Trainham *et al* (1945) followed twin infants from 3 to 32 weeks They were breast fed whenever they cried regardless of time of day At the beginning feedings were randomly distributed over the 24 hour day But gradually there emerged a three times a day schedule during the daylight hours Prior to the self demand experiments, because of the general practice of imposing a schedule, the natural tendency toward scheduling was hidden It is clear however, that with regard to other physio*logical processes*, such as breathing heart rate etc, a stabilization occurs within time in early infancy, which involves moving away from wide and irregular swings to a regular and patterned function Studies of sleep in the infant and young child show substantially the same evolution of pattern

But over and above the needs based *upon appetites there is another important* phenomenon, namely, the fact that the human is oriented toward external stimulation, is tremendously interested in it, and continually seeks more of it Through this adient process the child builds up patterns of behavior which fill in his time or the intervals in which he is not occupied with satisfying basic appetites In other words, *the human being is an active, seeking* organism that is highly responsive to external stimulation This is shown in his curiosity and manipulative tendencies, which are also revealed in the spontaneous play of the young in other species of mammals

If we now put this active seeking person into an environment that is reasonably stimulating, a very complex pattern of behavior which involves many specific acts, will develop If we look at the whole, it will be found that the waking time of the organism is filled with activities which bear *some relation to each other* There will be a regular alternation between sleeping and waking there will be periodic satisfaction of hunger and thirst, there will be a schedule for excretory activity and, after puberty some patterning to sex activity *within* larger units of time There emerges a basic *schedule of appetite satisfaction* with the interspaces occupied by other activities In the human this tendency is complicated by the demands made to react to specific stimuli and by imposed learning patterns which require the organization of activities in certain ways within time Even the briefest examination of ordinary living in our society reveals a high degree of scheduling or ritualizing With age there is a movement toward economy within particular systems and the interrelations of systems The living organism comes to handle the ambiguities of experience by ordering its behavior and as Sherrington showed years ago the nervous system with its principle of the final common path, is par excellence a device for integrating the complexities of the environment into the patterns by

means of which life can be ordered and tolerated

We must not identify human activities too closely with biological needs Wherever we find human beings, we find much time given over to artistic, musical, and entertainment activities, along with the spontaneously organized tests of strength and co-ordination which in more advanced societies we know as athletics or sports In a sense these activities are carried on over and above the immediate demands of the particular environment and serve partially as time filling activities and partially as means of channeling the organism's need for activity into particular contents Moreover, human beings derive substantial satisfactions from these activities There may be some point to the aphorism that people do not stop playing because they grow old they grow old because they stop playing

Another feature of the ordering process of particular importance for humans should be mentioned This is the freedom that comes to the person to attack other problems presented by the environment because some features of his life have been ritualized This applies to ordering both within systems of behavior and between systems of behavior A striking outcome of learning a response to a particular situation is the ability to meet the situation subsequently within a much shorter period of time and with a much smaller expenditure of effort The outcome of placing activities and tasks within the time schedule at particular moments usually makes for efficiency and also saves time and energy From the standpoint of the total time available, both practices free the individual to react to other features of the environment and in some instances, at least, to develop more elaborate and complex activities

IV Culture, Scheduling, and Energy Expenditure

In order to complete the picture, we must add the fact that the human being develops not as a solitary organism but in close relation to other persons who are similar to him Hence there is superimposed upon his activity patterns a type of structuring that is related to the wishes and actions of other persons He comes into a society which is preformed, which places values upon some activity patterns to the exclusion of others, and which regulates in some degree the amount of time and the order in time of the activities Hence the outcome or the way in which the person, with his basic tensions and needs, his strong drive toward the stimulation in his environment, and his free pattern of movement, meets the environment becomes so complex that we have difficulty in disentangling the threads that go into the final patterns The process of adapting the young human being to these social demands is now generally called "socialization" Socialization involves the development of ways of responding to primary needs in conformity with the restrictions imposed by society and is a process that extends over many years

As a result of socialization in the broadest sense the older person becomes a file or storage unit that contains many well established patterns that suffice to meet the demands of the environment, unless radical changes occur As ordering goes forward, the person reduces more and more of the new situations which arise to familiar situations met by established habits Presumably with age he reaches a point where most of his daily life is occupied with familiar tasks rather than with developing new activities What I am suggesting is that there is not only an ordering within habit systems but one also between systems of behavior This would gradually reduce freedom and create an atmosphere in which the person finds it increasingly difficult to find new and engaging activities Hendrik Van Loon once said that a man was old when there were no more *new* books to read No one has, however, taken a look at the scheduled activities and habit systems of older and younger organisms as

totalities and compared them in order to see the relative areas of freedom and con straint which emerge

An obvious problem in connection with the expenditure of energy and development of activities arises out of the relation be tween the cultural and economic status of the society in which the person lives and the types of activity patterns which he develops In many primitive societies espe cially those in areas with limited resources, virtually all the available time and energy of individuals goes to searching for and preparing food Little time is available for other activities More advanced communi ties store food and distribute it through specialized agencies and persons and thus free other persons to carry on other ac tivities Before the era of modern ma chinery freedom was secured for intellec tual and cultural activities through the use of slaves who did the heavy work necessary for the maintenance of the citizens or free men who could then devote their time to intellectual, governmental and military ac tivities In modern society, by using ma chines as sources of energy we have freed much of the time and energy of the citizen for other activities Labor saving devices of all types operate in this way

Recently very great changes in the ac tivities of large numbers of persons have occurred as a result of these social changes The reduction in the length of the work week gives great numbers of men much more leisure time, which may be filled by another job or used for recreational and cultural activities Labor saving devices in the kitchen and laundry have freed modern women from the drudgery of a century ago As a result there have been great increases in the employment of women and in their participation in a wide variety of activities In a period of very rapid social change, older persons may have somewhat greater difficulty in making these shifts than do younger persons who grow up with the machines, learn to use them, take them as a matter of course, and build secondary systems of activity which fill their time schedule Older individuals who have not accommodated to the changes find them selves with time on their hands because the well established habits built up during an older cultural pattern have been outmoded

Some account should also be taken of the fact that in our ordinary life patterns, especially in the highly industrialized so ciety in which we now live, we have changed the activity pattern of the or ganism radically by reducing the amount of physical effort necessary to maintain life and to satisfy basic needs by substi tuting sedentary and inactive pursuits We let machines do the heavy work of living and ride rather than walk In our sports we become spectators who watch specialists take the active exercise This has been called by someone "a change from the feet to the seat," a quip which illustrates the shift from the active life for and in which our bodies have evolved to a stationary and sessile type of life for which they have not evolved

V Motivation of Older Persons

In animal studies it has been found somewhat more difficult to motivate older animals for performance than younger ani mals Stone (1929*a*, 1929*b*) had to deprive the very old rat of food for a much longer period of time prior to running the maze in order to produce approximately equiva lent performance in maze learning This suggests that, in an environment without demands or reinforcement, an organism would decrease its activity level with age In human beings, however, the situation is complicated by social demands, by feed back, and by reinforcements which change the motivational pattern and thus keep the organism active This flexibility is char acteristic of living systems In other words, a human being can overcome in some de- gree, under appropriate incentives, the tendency to decrease his activity level with age Nevertheless, casual observation shows a strong tendency for men and women as they grow older to move from the more

strenuous and more demanding types of voluntary athletic and sport activity to the less demanding and less strenuous activities In professional sports, especially those of the more vigorous type, a man is considered old at 40 Lehman (1951) showed that the most proficient years in sports and games were those between 25 and 35 years

In the time stress studies of Welford and his group (1951, 1958) (see chap xvii), in industrial work it is clear that there is a marked decline in the number of workers who continue in the speeded up, high energy consuming activities The downward shift seems to begin at about 45 years and thereafter to become more marked until at 60 very few indeed are left Whatever it is that produces this phenomenon in large numbers of workers may have a significant relation to what older persons do in other activities

It is clearly very difficult to secure a base line for energy expenditure and motivation Under specific test situations in which the old person knows he is being measured, he may for a short time whip himself up to such an extent that a false picture is given of his energy expenditure when considered as a whole In fact any formal test or exercise under controlled conditions may give a very inaccurate picture of what is happening with the person In order to counteract the deficiencies of the formally set measurement situation it has been proposed that studies be made of the individual's self oriented and self initiated activity by observational techniques akin to those of Barker and Wright (1955)

Moreover, the structuring of behavior which occurs in the skill and knowledge components of behavior also occurs in work habits and attitudes This makes for an adaptive economy that maintains functional efficiency Often the older person rests in off periods in order that work may go forward at a constant rate in work periods, while the younger person plays at active games Hence it is quite possible that measures of activity level made outside the competitive and structured situation better reflect the general state of adaptation in terms of energy level

It is also clear, even though it is difficult to cite specific studies, that in the course of his experience the person acquires certain work habits, such as starting a job promptly, carrying through to the conclusion of a task, expending time systematically persisting beyond the first feelings of fatigue pushing through in spite of minor errors to the completion of work, etc, which affect efficiency as measured at various age levels Such factors are in part related to the intensity of motivation in the particular situation and are in part the product of the person s life experience in organizing his energy and activity patterns

It is frequently said that older persons fail to solve problems because they are not motivated to attack the problem and that they fail to learn because they are not motivated to try Such statements imply the full retention of capacity It is also clear that various emotion laden outcomes of their earlier experience, such as worry about errors because of an overemphasis on accuracy or concern about making fools of themselves in the presence of their associates, may have an effect on their participation

This is an area in which we need much more research The recent study by Botwinick *et al* (1958) which showed that motivation does not account for the increase in the latency of responses with age, suggests that we should be careful in assigning responsibility for changes to motivational factors and should concern ourselves with disentangling the relations between factors

VI The Work Life and Productivity

In the life of the person a major distinction can be made between the activities carried on in order to earn a living by services or products which can be exchanged with the services and products of others and the activities which the person carries on because of his own interests in

the leisure time he has available The work pattern can be defined as the expending of energy in activities which are imposed up on the person by the requirements of living in a society which demands that the activi ty proceed in an orderly manner within space and time toward goals Although in a few instances the demands of work co incide with the person s own wishes in most cases in modern society there is some sep aration between the self initiated activities of leisure and the demands of a job The relation between work and satisfying needs is mediated in our society by intervening processes especially by money which be comes at once a standard of value a goal and a medium through which products and services are exchanged In more primitive societies the relation among need want interest and activity is much more direct

Coupled with the work area is the edu cational or training area which covers the years in which the person under guidance and supervision acquires the skills and competencies necessary for adult life Al though education begins in the early years with much freedom it gradually assumes more and more of the characteristics of work However broadly we define the pur poses of education nevertheless it is the primary agency in our society for adapting the growing person to the demands of adult society This holds both for the content of the skills and knowledges and for the hab its of work, responsibility and motivation

Since the major time filling activity for the adult is work, we can well ask what work does for him as a person In consid ering these outcomes no distinction need be made between men and women since for married women homemaking can be re garded as a specialized form of work with the same attributes as the work of males What then does work do?

First, work involves tasks or responsibil ities which involve the exchange of prod ucts and services with other persons As a result there appear specific jobs upon which others and society itself come to depend These social roles are recognized as such both by the individual and by society itself

Second, because work has continuity and permanence, it becomes a center around which much of the thinking, fantasy, con versation, and activity of the worker re volve He identifies himself with the role and obtains a kind of security which stabi lizes his personality

Third since work activities require skill, the person learns the necessary skills and soon responds to various aspects of the tasks in ways that other people, who are relatively unfamiliar with it, cannot. In many types of work, the activity moves toward greater complexity and thus in creases the skill demands and holding power of the job But society seems to ad vance by breaking up complex jobs into simpler and more isolated skills and thus produces monotonous work This forces the person to seek complexity and elaboration in leisure activities outside of work

Fourth, it is clear from the studies of Friedman and Havighurst and others (1954) not only that work has activity con tent and time filling characteristics but that it also involves many social relations The worker is a member of a team—an office staff a gang, a company, etc—that is, a group with which there is much communi cation all through the day These social re lations not only are reinforcements but also have sustaining value for the person

Because work tends to be universal in our society, we take it for granted and do not ordinarily ask about its contribution to the adjustment of the person Generally, we think of lack of work as bad and assume that persons without work are likely to get into trouble With older people, especially those who have retired, the problem of meaningful time-filling activities becomes of importance as we shall see later But there is one study by Kleemeier (1951) in

ble health status These differences extended to all aspects of the adjustment inventory health, work, feelings of usefulness, and happiness Presumably, similar results would be obtained at other ages

Next we may ask about the effect of age upon efficiency in working It would seem, offhand, that much data would be available on productivity and age on ordinary workers for many types of jobs But very little is available, possibly because work requirements differ from job to job and can be met in various ways by individuals at different age levels In the Smith (1938) study, done under laboratory conditions, and using 4 hours of uninterrupted assembly of nut and bolt units as the task, the work of the 30 year old group was set at 100 per cent The average output decreased to 94 per cent in the 40 year old group and to 86 per cent in the 50-year old group Brozek (1956) pointed out that there was no information in textbooks or the scientific literature on industrial psychology on changes in working efficiency with age, even though changes in underlying psychological functions received much attention Yet statements continue to be made that older workers are more efficient than younger or vice versa

Since Brozek made his statement, two studies have appeared that deal with actual production measures One by King (1956) finds that women operating power sewing machines on a piecework system reach the peak of production at 30 years and that after 35 years there is a slow decline, which seems to be similar to the decline found in sensorimotor tasks in the laboratory Clay (1956) studied age and performance for readers, hand compositors, and machine compositors in two printing plants which used incentive schemes Declines with age were small but were observed from about 50 years and up in compositors but not in readers Variability among individuals also increased with age

The studies described by Welford (1958) indicate the complexity of the factors involved in such problems Time stress in jobs which emphasize speed will produce decline Kay s work (1955) shows the difficulty of the task is related to age Hence decrements with age may be expected in the more difficult or complex tasks

Counteracting these tendencies is the effect of long experience and the level of skill developed In some types of highly skilled tasks, relations with age may differ greatly from those which hold for tasks at lower levels of skill It is clear that the assessment of changes with age in the "functional efficiency" of the person presents many problems and involves not only direct measurement under comparable conditions of task performance but also some analysis of the age changes in the ability and skill components, together with some analysis of the motivational factors involved Further, we need some analysis of the extent to which compensatory and corrective adjustments with age can be made within the demands of the tasks when we view the tasks as organized systems of behavior made up of interrelated components

VII Productivity and Age

In order to gain some insight into the relation of productivity to age in the human being we may turn to the work of Lehman (1951 1953, 1954 1957), who studied the productivity of distinguished persons in a wide variety of intellectual, cultural, and scientific fields In chapter xx of this book, Jones discusses Lehman s results with regard to creativity Here we are more concerned with the studies as measures of productivity We assume that most of the persons studied by Lehman are dedicated persons who have devoted most of their lives to activities for which they were strongly motivated In many instances these persons did not work in the ordinary sense in which a person punches a time-clock at eight and five o'clock But they worked hard and, compared with other persons of lesser capacity, were usually able to set their own pace They, then, are a group well out toward the upper limit of the distribution in terms of abilities, of

creativity, of motivation, and of social recognition

Lehman's technique consists in locating objective records of performance, such as the dates when poems or novels were published, inventions patented, scientific articles appeared musical compositions were written or published, etc , and checking these against the chronological age of the individual who produced them and then tabulating or plotting the results against age For motor performances he turned to athletic records which are published in detail for various activities, and tabulated the results with respect to age Then within and across areas many comparisons can be made It should also be pointed out that he developed many internal controls in his data, such as comparing long lived individuals with short lived ones, different historical periods, different cultures, and individuals of extraordinary attainment with those of lesser attainment (but distinguished also) within the fields For the persons to be studied within the different areas of endeavor, he used mention and citation at various levels in histories, biographical dictionaries, lists of outstanding performers, standard textbooks, and similar sources Within each field he had the cooperation of specialists and of various organizations that located sources for him and assisted him in the selection of outstanding persons In his numerous papers and his book (1953), which represent a lifetime of study, a tremendous wealth of data is presented Two types of analysis are made one in terms of the quality of performance as shown by the highest rated or most outstanding performance, and the other in terms of the quantity of performance or the total output of the distinguished person

TABLE 1*

PERCENTAGE OF QUALITY OUTPUT CONTRIBUTED DURING EACH DECADE

Field	Age							
	Under 20	20–29	30–39	40–49	50–59	60–69	70–79	80–89
Chemistry	1	23	39	23	11	3		
Mathematics	1	19	34	20	15	7	2	
Physics		21	35	27	11	5	1	
Inventions	3	27	38	20	8	3	1	
Psychology		22	36	21	15	5	2	
Physiology		12	37	20	22	8	2	
Anatomy	1	30	33	23	9	2	2	
Education		15	41	19	17	7	1	
Economics and political science		2	48	34	10	6		
Grand opera	1	19	32	25	16	6	1	
Orchestral music	2	12	43	22	17	5		
Paintings		18	31	23	18	7	2	
Philosophy		10	34	32	17	5	2	1
Influential books		1	37	37	14	11		
Best sellers		10	28	47	8	7		
Lyrics and ballads	3	53	20	17	3	3	1	

* Source After Lehman (1953) Tables 23 and 24 pp 141–43

In the studies of productivity in various intellectual and artistic fields, the highest productivity tends to come in the earlier periods of life, even though there is some variation from field to field From the voluminous data covering a wide range of fields, I have selected the material in Table 1, which shows peak productivity in the decade between 30 and 39 years, except for

quantity of work produced by individuals,

since it is based upon lists which identify contributions to the fields listed Note the striking similarities when fields are compared

Much attention is also given by Lehman to the problem of the quality versus the quantity of production In general, the technique here is to separate the most outstanding works or products from the general mass and calculate the age relations for the outstanding performances and for all the works of the person In general, the finding is that the most original and creative work comes earlier Much of the discussion in chapter xx and the criticisms by Dennis referred to in that chapter center about this point As an example of Lehman's findings consider Table 2 which presents results for a number of fields It should be noted that by Lehman's criteria the quantity keeps up after the quality has fallen off in relation to age But ultimately the quantity falls also In Figure 2 an analysis of the quantity versus quality of output is presented based upon the best publications of deceased philosophers compared with the curves for their total productivity Notice that the curve for quality as determined by these standards drops after the age of 40, whereas the curve for quantity of production stays up until the early seventies

In a special study of the productivity of Thomas A Edison (whose inventions are a matter of public record) for his whole life-span, Lehman obtained the interesting curve shown as Figure 3 There is a very high peak around the age of 35 years, a decline at 47 and 48 years, in which there was no productivity, a secondary peak around 57 years, and a third peak between 70 and 75 years, which arose because of the stimulus of World War I But there was productivity throughout the whole period from 20 up to 83 years Although this

TABLE 2*

QUANTITY VERSUS QUALITY OF PRODUCTIVITY IN RELATION TO AGE

Field†	Age										
	20–24	25 29	30–34	35 39	40–44	45 49	50–54	55 59	60–64	65 69	70–74
Chemistry											
Quality	015	096	159	141	079	048	027	010	011		
Quantity	017	196	167	204	267	259	275	243	205	197	180
Psychology											
Quality		028	032	080	056	058	030	024	032	013	
Quantity	067	289	559	713	764	741	520	446	456	333	343
Philosophy											
Quality	004	016	037	037	032	028	017	023	010	011	008
Quantity	041	135	237	218	226	198	192	184	224	164	230
Painting											
Quality	021	068	101	142	151	069	073	039	033	049	033
Quantity	067	149	220	234	221	202	189	157	165	160	104
Literature											
Quality	025	081	124	110	113	056	035	053	033	024	011
Quantity	211	383	475	448	522	463	439	490	463	420	383

* Source After Lehman (1953) Tables 34–41 pp 242 49

† Philosophy one best book versus total others super or publications versus total

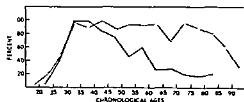


FIG 2—Quantity versus quality of output of 182 deceased philosophers *Solid line*, one best publication *broken line* total publications (After Lehman, 1953)

individual curve is difficult to interpret in the absence of all the details about Edison's life, it is similar to some of the curves ob tained through averaging the production of many gifted persons Lehman (1953) also presents data for other individuals in his major report These suggest the desirability of more detailed studies in individuals of

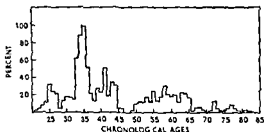


FIG 3 —Edison's productivity at various ages (After Lehman 1953)

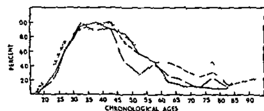


FIG 4 —Age and production of literary works *Solid line* American authors *broken line* German authors, *dashed line* French authors *dotted line* British authors (After Lehman 1953)

the relation between productivity and other factors which are on record in order to reveal the significant factors underlying age relations

The effect of cultural background upon productivity and age for miscellaneous lit erary works is shown for German, French, American, and British authors in Figure 4 Note the basic similarity of the curves This suggests that within our occidental culture, national differences in performance in relation to age are small More recently, Lehman (1954) has made a similar analysis of production rates in relation to age for science and mathematics in which he has compared Russians, Englishmen, Italians, Frenchmen, Germans, and Americans He found that the age curves were very similar, with the maximum rate coming between 30 and 40 years of age and a fairly uniform decrement per decade thereafter Some production, however, is still found in the decade from 70 to 80

In Figure 5 we have Lehman's answer to the question that he fails to take account of longevity in his studies of the quality of production Figure 5 shows contributions to ten fields of science by men who lived to 70 years or beyond, compared with those of men who died prior to 70 There is no essential difference in the form of the curves In Figure 6 Lehman presents the age relation of contributions by chemists and then corrects this curve for the output

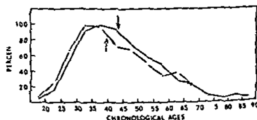


FIG 5 —Longevity versus production in fields of science *Solid line*, men who lived to 70 or beyond, *Broken line* men who died prior to 70 (After Lehman, 1953)

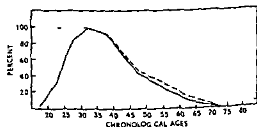


FIG 6 —Age versus contribution by chemists [illegible] contributions as listed, *broken*

[illegible]

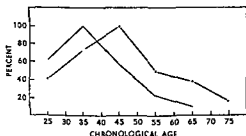
1953)

if each chemist had lived to be 80 There is a slight difference in the later part of the curve but none in the peak This curve also shows the percentage of the original number of chemists who were still alive at successive age intervals

In Figure 7 a comparison is made between the production of physicists based

on 45 physicists born prior to 1785 and 44 *born between 1785 to 1867 Note that the* peak for the physicists born prior to 1785 is at the age of 45, whereas that for those born after 1785 is at the age of 35 Thus quality production in science tends to come at earlier ages when studied later in time Lehman buttresses this finding by studies of geology, mathematics, botany, medicine and public hygiene, philosophy, educational theory, economics and political science, etc There are, however, some exceptions to the principle These occur in practical inventions, for which the curves peak at the same age, and for pathology It is possible however, that studies made in the present would show a reversal of this trend because of the longer training now required and the greater mass of knowledge that must be mastered to move into new scientific problems and areas

In addition to studying intellectual and cultural performances Lehman has also analyzed motor and athletic performances by plotting the ages at which championships are attained or world's records established In Figure 8, curves from Lehman's



Lehman 1953)

book (1953), relating the quality of output in science with championship proficiency in seventeen types of vigorous skills to age is presented Note that peak performance for both areas comes between 25 and 35 Top proficiency in vigorous athletic skills (boxing, baseball, track, etc) is gone by the age of 40, whereas the top scientific output continues at a declining rate into *the eighties In Figure 9 Lehman* compares quality output in science with championship proficiency in the fine motor skills (golf, bowling, billiards, etc) that do not involve strength and speed The peaks of this curve coincide with that for quality in science at 34 years, as compared with

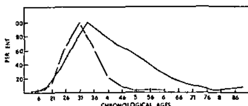


FIG 8 —Age and scientific output versus age and proficiency in vigorous skills *Solid line* superior contributions in various scientific fields *broken line* championships in 17 classes of vigorous sports (After Lehman, 1953)

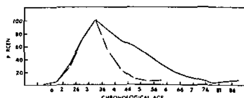


FIG 9 —Age and scientific output versus age and proficiency in skills of fine co-ordination *Solid line* superior contributions in various scientific fields *broken line* championships at golf billiards shooting bowling etc (After Lehman 1953)

the peak for vigorous skills at 30 years There is, on the average, then, a 4 year difference in the ages at which championships are attained when vigorous athletic skills are compared with those which emphasize quality of co ordination

Lehman s results (1951) show that in almost every athletic activity peak performance comes between the ages of 25 and 30 years A large proportion of all the world records made in the last 50 years in many different sports have been made by persons near 25 years of age Records of the same athletes over a period of years show that, if a young man breaks a world record at 19, he is likely to set his final record somewhere around the age of 25

This study of individual and group records, then indicates that the maximum physical efficiency of the human organism is found, on the average, around 25 years of age and that by the age of 40 years in the com petitive situation, with its emphasis on speed and strength, aging is already well along Nevertheless, it should be emphasized that for the ordinary demands of work in our society the person at 40 is far from old

That the changes in athletic performance are to a large degree independent of the particular period and are tied in with de velopmental processes is shown by a com parison made by Lehman of early baseball

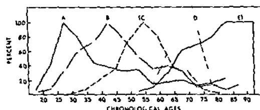


FIG 10 —Age versus productivity and social achievement *A* superior poems *B* superior novels and other prose *C* recipients of incomes of more than $100 000 *D* speakers of House of Representa tives from 1900 to 1940 *E* popes (the last twenty six deceased popes) (After Lehman 1953)

records with those of a later period For both periods outstanding records were made mainly by players around the age of 25 years, and the age curves were very similar, even though the standards for pitching, base running, and batting had changed This suggests that, in considering age relations of tasks we could well analyze the developmental picture in terms of the components or basic factors which, when combined into tasks, in some degree set bounds for the content and character of the performance It also should be clear that in sports there is very high motivation in terms of social recognition, financial recompense, etc Yet age declines take their toll and send the person back to a lower level of performance, which in a short time forces him into other activities

Very recently, Lehman (1958) has pub lished an extensive analysis of the produc tivity of the world's 2500 ablest chemists, in which he confirms his earlier findings and pays particular attention to the rate of production He finds that the greatest rate of production of the highest quality comes between 30 and 35 years but that the high point for minor productions comes at 40–45 years and that the rate for pro ducing minor as distinct from major pro ductions remains high throughout the whole life span in the case of the most outstand ing chemists For chemists of less notable production, the rate is highest between 35 and 40, and the production of all types of work, including minor productions, falls off much more rapidly than that of the out standing chemists

In Figure 10 there is a curve showing the relation between age and various measures of accomplishment, some of which involve creativity and some of which involve social recognition The peak age for the production of superior poems is between 25 and 30, for the production of superior novels essays, and prose, between 40 and 45 for high earned annual incomes, be tween 50 and 55, for speakers of the House of Representatives and the prime ministers of England, between 70 and 75, and for the last twenty six deceased popes, over 80 This reveals a differential age spacing in terms of social recognition of accomplish ments Obviously the measures shown are based on very different factors Presuma bly this is true of a wide number of human activities involving social relations How do they get bound to age levels?

Although Lehman's work has given rise to much controversy, in justice to him it may be said that he points out the many discoveries and productions of great social value which have been made by older persons and records instances of astounding

ordinary persons his results, nevertheless, probably come nearer to revealing what is

characteristic of persons working near their maximum capacity, because they are in some degree free of the imposed production limit characteristic of most workers In a sense what is presented here is the level and amount of their finished products which give an indirect measure of the fertility of their ideas and their persistence and energy in pursuing them If we had absolutely complete records of work, including the preliminary states and partial attainments necessary to organizing final products, we would have, probably, an even more striking relationship It should be pointed out also that there are persons in our society who under pressure of hobbies or special interests work very hard and energetically over very long periods in pursuing activities which lack the public or striking social outcome that is true of these particular men. It would be interesting to make a special study of such individuals Unfortunately, however, the dating of accomplishments presents much more difficulty than is the case with individuals who achieve distinction

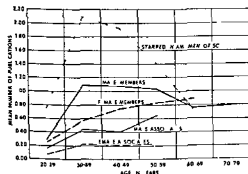


FIG 11 —Mean number of publications per year by American Psychological Association members and associates (After Anderson and Goodenough 1935)

In interpreting Lehman's findings, we may turn to two studies which were made across whole professions and which, therefore, selected individuals within the professions that published but did not select them in terms of quality, even though some analysis was made in terms of level

The results of the first study, by Anderson and Goodenough (1935), based on an analysis of the data in the *Psychological Register* (1932), are shown in Figures 11 and 12 The study was restricted to the various classes of members of the American Psychological Association, including those starred in the *American Men of Science*, who were treated separately Figure 11 is

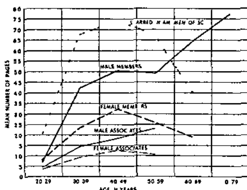


FIG 12 —Mean number of pages published per year by American Psychological Association members and associates (After Anderson and Goodenough, 1935)

based on the mean number of publications per year, Figure 12, on the mean number of pages published per year Note that, depending upon the measure used for this data, somewhat different age curves are obtained For the number of papers the peaks tend to come between 30 and 39 in all membership classes, whereas, in terms of the mean number of pages, peaks tend to come between 40 and 45, except in the case of male members, for whom the peak is in the 70–79 period This relation exists because psychologists at the older age levels wrote many more long textbooks and summaries This suggests that the better measure of productivity is the number of publications For number of publications the productivity of female members is under that of male members up to 50–59 years but is above at 60–69 years Male associates are next in order of amount of publication, and female associates least Psychologists starred in *American Men of*

Science, who presumably come somewhat nearer in ability level to the outstanding persons Lehman studied, show a peak for the mean number of publications at the 30–39 year level and a peak for the mean number of pages at the 40–49 year level, with a sharp drop thereafter This may be the result of many being drawn off into administrative work or acquiring other types of social responsibilities

Another approach to the data is shown in Figure 13 which shows the relation of the number of fields in which publications are

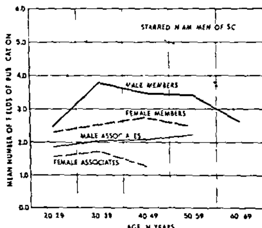


Fig 13 —Mean number of fields of publication by decades by American Psychological Association members and associates (After Anderson and Goodenough 1935)

found Here the striking relation is the number of fields in which the outstanding psychologists published in their earlier years, with some restriction later on, as compared with the four membership classes which remain fairly stable in breadth of interest over the years

A study made by Richardson (1936) of the publications of mathematicians analyzed the relations of publication in successive 5 year periods after receiving the Ph D degree The first 5 years seemed to be the most prolific period, with some falling-off during each subsequent 5 year period There did not seem to be much change with age after the first 5 years in the rate of publication from the first to the seventh 5 year period Productivity was kept up into the later years A relation between earlier and later productivity also appeared

The latter problem has been studied by Dennis (1954), who used data on psychologists from the *Psychological Register* and on recently deceased members of the National Academy of Science from the *Biographical Memoirs* of the academy

He found substantial correlations between productivity in the different decades of life for these groups, indicating that individuals tend to be consistent in their rates of publication from decade to decade Dennis also studied total productivity of these groups and found a peak for the psychologists in their forties, with maintenance of level thereafter, while the academicians show a peak in the thirties, with a high level maintained through the fifties and with a decline in the sixties

From these various studies of creativity and productivity in relation to age, it seems to be clear that maximal physical efficiency comes in the period between 25 and 40 and thereafter declines and that creativity or high-quality productivity in various intellectual and cultural fields is more likely to appear between 25 and 40 and then decline But, when the quantity of production is measured by decades, there seems to be no such marked decline Productivity rates within the decades of adult life are highly correlated It is reasonable to suppose that this would also be true of creativity or quality measures It is quite clear that these are general trends and that individual instances of productions of the highest quality appear in all decades of adult life

VIII Interests and Activities

Another distinction may be made The adult works under the demands of time and place In the time in which he is not working or satisfying basic appetites, he engages in activities which we call leisure, play, or recreation In the main these interests and activities are self initiated and are freer

with respect to demands than is work But it is also true that many play and leisure activities have rules and requirements which have to be met and from the standpoint of the energy needed may be more demanding than work, at least temporarily Such secondary activities fulfil a necessary and useful function in the life of the person

We often, however, speak of such activities as play, and thus we classify them with children's play This is an error Play particularly for the young child and in some degree for the elementary school child is a part of his work in the sense that he is spontaneously developing the cognitive skill, and social components which he will find useful in later life Much of the child's activity consists of the searching manipulatory, verbal, and repetitive activity that builds up his perception of the objects and persons about him and enables him to react appropriately to them Even most of his toys and playthings are miniatures of the adult objects he is likely to encounter In the adolescent more play activity takes on the secondary and leisure time character than we associate with the recreational activities of adults and thus relieves the tensions created by work demands

The distinction between work and recreation is of great importance in our society, which intensifies the demands of time and space by speeding up production while it reduces the hours in which the individual is in the controlled situation of work This aggravates the time-stress relation and sharpens the distinction between work and leisure activities during the working life From the developmental point of view, however, work for most persons is itself the outcome of a channeling process that started earlier in life and involves selection of one area from among various possible interests and activities

In a real sense a person can be defined

there is a relation between the individual's verbal expression of his interest and his activities, what the person does shows more clearly how he has organized his life pattern within the time he has available Although many studies have been made of the interests and activities of children and adolescents with similar techniques over a wide age range, relatively few have been made of adults or older people, and these generally were for rather specialized purposes rather than to reveal basic trends We need to know about how the person at every age level uses his time and what activities concern him in order to obtain information on the manner in which the display of energy becomes organized within the life cycle of the person

Range of Interest in the Developing Person

A type of study which shows how energy manifestation in younger human beings is organized is found in the studies of the range of interests and activities Lehman and Witty (1927) carried on such a study, with results that have been stubstantiated by other investigators of which the latest is by Templin These studies show the greatest range of interests and activities among children around the age of 9 years and thereafter, up to the age of 22 years, a steady drop year by year in the variety of interests Brighter children at each age have more interests than do average children and boys slightly more than girls The changing pattern of interest with age is often interpreted as indicating that in the life-pattern there is a gradual shift from breadth of interest to depth of interest and that the mature person pursues a smaller number of activities with more intensity and depth In a sense the younger person is exploring himself and his environment, while the older one has settled on a few courses of action If we look at this process, it becomes clear that efficiency is purchased at the cost of versatility Thus there is a truncated pyramid with a broad base and a narrow top which represents the actual use of time Paralleling this development, the

growing person builds up a reservoir of patterns which increases with age and which makes available a much greater repertoire of skills and activities and knowledge than is true at earlier years

Hence the growing person moves through situations standardizes or ritualizes his reactions to them and then moves on to others We do not know yet enough about in-

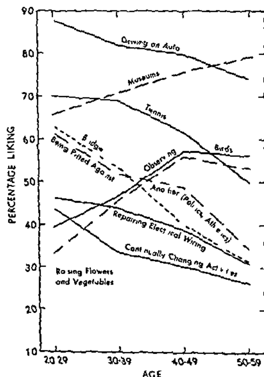


FIG 14 —Changes with age in various interest items on the Strong Test (After Pressey and Kuhlen 1957)

terest patterns in this sense in older individuals to be able to generalize over the whole age curve, but many observers comment upon the self imposed restrictions in activity and interest patterns that arise in aging and have raised the question of how older persons can be restored to an earlier state in terms of a zestful outlook on activities and interests

Once the person has reached maturity, his interest patterns acquire much stability within broad areas This is partially forced by the fact that in our society adults have highly specialized roles which are maintained by the specialization of activity and by the concentration on particular skills and interests rather than upon the whole range that characterizes the younger person A striking example is the degree of specialization within vocations Although some of the breadth of interest is preserved in recreational and entertainment activities, even here there is evidence of much patterning and specificity It must be remembered that there are wide individual differences and that at all ages there are a few individuals who are extraordinarily alert to all aspects of their environment

Strong (1931), in a study of changes of interests with age, analyzed the results of the Strong Vocational Interest Blank on 2340 men varying in age from 20 to 59 years These men were of a fairly high educational level, as they were professional or semiprofessional people for whom the Strong Interest Blank is primarily used While there were changes in the liking and disliking for each of the more than four hundred items which make up the questionnaire, in general, interest patterns showed high constancy with age in terms of summated scores

On the whole, there is little change with age in the proportion of likes or dislikes, the amount of change from 20 to 60 years being only about 7 5 per cent Moreover, analysis indicated that change does not take place uniformly, as most of it takes place between 25 and 35, relatively smaller amounts between 35 and 45 and 45 and 55, and almost no change after 55 It is also quite clear that the differences between individuals in interest patterns are much greater than are the differences between the various groups

One can go through the data and pick out items which show marked changes downward, marked changes upward, or little or no change with age For example, there is an increased liking for magazines such as *National Geographic*, an increase in liking for spending evenings at home, an increased interest in art galleries, an in-

creased interest in making a speech, and an increased interest in becoming secretary of a society, but there is decreased interest in driving an automobile, in musical comedy, in playing tennis, in changing the activity pattern, in exploring, etc On the other hand interest in such items as listening to a symphony, reading detective stories, being an undertaker, etc, show little relative change with age

Figure 14 shows the differential picture which is obtained when items are plotted against age In this chart a distinction is made between the active and competitive items and the more sedentary and non competitive types of activities

In general, items suggesting physical skill, daring, or strenuous activity show the most marked decrease in interest among the men, and the second most marked rate of decrease is in the items which suggest some change or interference with established habits or cultural pattern With few exceptions the liking for a variety of occupations decreases with age and the liking for a particular occupation tends to increase There seems to be some decrease for men in linguistic activities of an oral or written nature, while an increase in activities involving reading appears There seems to be a general increase in liking for the items which we would call cultural and some decrease in the items which center about amusement There also seems to be some increase in the liking for solitary activities in preference to those involving group activities and an increase in liking for persons with desirable and in disliking for persons with undesirable personality characteristics Older men also seem much surer of their estimates of themselves There is also some indication that what is liked most at 25 years is liked better with increasing age and that what is liked less at 25 years is liked still less with advancing age

In a longitudinal study of interest scores over a 22 year interval, Strong (1951) used data obtained on college seniors first tested in 1927 and retested in 1932, 1937, and 1949 He found correlation coefficients of 84 for the 5 year, 82 for the 10 year, and 75 for the 22 year interval These indicate high permanence of interest over a substantial period of time In an analysis of the relation of permanence to age, he found that, the older the person was at the time of first taking the test, the more permanent were the interest patterns

In an old and unpublished study by Symonds, cited by Shuttleworth (1938), broad areas of interest were studied from adolescence through to the 50 year level With respect to interest in the opposite sex, the changes in men were slightly downward in later ages, but, on the whole, men throughout life seemed to be interested in the opposite sex Among women, however, significant changes appeared after the menopause in the direction of lessened interest in the opposite sex Among women interest in personal adornment remains high up to the ages of 45 and 50 and then drops while among men exactly the opposite result appeared in the form of an increased interest in personal adornment With regard to money, among both men and women, interest increased during maturity, with interest somewhat greater among men than among women After the age of 45 or 50 for the majority of persons, the interest in money decreased, whereas in a smaller proportion the interest in money steadily increased Obviously, money is tied in with both the security situation and the power situation in our society Older persons of both sexes become more interested both in themselves and in their relation to the universe as reflected in an increase of interest in the philosophy of life Interestingly, some support of this view came out in the studies made by Lehman who found that older writers turned more and more to philosophical and interpretive writing

In the Terman and Miles study (1936) of the masculinity and feminity of interests and attitudes, the analysis of age relations shows the highest masculinity of interests characteristic of the male at the age of 16, with a quite uniform decrement in each

decade thereafter and the lowest point in the eighties The 13 year old female shows the greatest femininity of interest with some movement toward masculine interests until 19 years and then more femininity until the fifties after which there is very little change

Activity among Older Persons

When we look at the literature for detailed descriptions of the activities of older persons covering many cultural levels we find almost no systematic studies over a wide range of ages under similar conditions with similar instruments At younger age levels by questionnaires by recording activities for a definite period and by time sampling techniques a fairly good picture can be obtained. In studies of hobbies and of hobby participation by Briggs (1938) and by Cavan *et al* (1949) on limited groups it was found that a fairly constant proportion of persons at each age level in the older years have hobbies the percentages running from 40 to 60 But this means that the remainder have no hobbies When we ask what old people do when they have no hobby or how old people spend their time relatively little data are available There is a study by Morgan (1937) in which he grouped the types of daily activity participated in by 381 people over 70 years of age into categories and obtained the following percentages

	Per Cent
Housekeeping housework helping with housework, and caring for grandchildren or for an invalid	32 9
Hobbies games and intellectual pursuits reading studying writing letters and playing music	31 5
Walking seeing and calling on friends club and church work	13 6
Resting sitting in the sun watching out the window "not much of anything"	9 6
Gardening flowers pets livestock chores	8 1
Employment at small jobs	4.3

Townsend (1957) presents an analysis of the activities and family life of older people in East London for which the material was obtained from diaries and by interviews

That participation in activities and the range and variety of activities in which older persons engage are related to cultural status and educational status is indicated in a number of studies such as that of Havighurst and Albrecht (1953) Apparently the amount of time spent in just loafing or doing nothing is much larger among laborers and unskilled workers who have retired than it is among educated persons Some of the literature in this area is summarized in Pressey and Kuhlen (1957)

In reporting on the interests and activities of older persons in terms of the present literature one major difficulty is encountered Since World War II television has entered the world and sets have been diffused throughout the United States as new stations have been opened Because television is so powerful in attracting interest and generally takes up a substantial amount of time each week other interests and activities are reduced When television is first introduced into a community there is a very great amount of viewing by all age levels after it has been available for 6 months viewers spend less time and are more selective Data on the amount of viewing time per person per week in rela

the adult level We need data on viewing in relation to age on older people We also need studies of interests participation and activity made after television has become widely available in the community

Some studies have been concerned in one way or another with the change in interest patterns with respect to the various mass media which attract so much attention. A study by Link and Hopf (1946) found that with age there was a decrease from 34 to 18 per cent in the persons between 15 and 60 who had read a book the previous day almost no change (from 84 to 83 per cent) in reading a newspaper a decrease from 51 to 35 per cent in the proportion of

persons who listened to a radio, and a marked decrease (from 27 to 6 per cent) in the proportion of persons who went to the movies the previous day

In a somewhat similar analysis by Schramm and White (1949) of the percentage of various items in newspapers read by members of various age groups he found that reading the comics decreased from 66 to 36 per cent for males and from 54 to 12 per cent for females between the ages of 20 and 65, reading of crime and disaster news went up from 21 to 31 per cent for males and from 23 to 31 per cent for females looking at news pictures decreased from 60 to 50 per cent for both sexes reading the sports news decreased from 32 to 14 per cent for men and went from 4 to 5 per cent for women reading news about public affairs went from 25 to 38 per cent for men and from 19 to 27 per cent for women, reading editorials went from 26 to 36 per cent for men and from 23 to 32 per cent for women, society news went from 7 to 11 per cent for men and from 14 to 15 per cent for women There was some variation in all these proportions in the intermediate ages What this means of course, is that to some degree whatever the type of activity or medium an individual is exposed to, he makes some selection in terms of his age level so that a relation appears in some areas and not in others

No attempt is made in this chapter to cover the practical literature on recreational activities for older people There are many agencies, such as day centers and Golden Age Clubs, working in this area which are not concerned with research or trends But research is needed and any studies undertaken are likely to have practical implications

IX Retirement, Time filling and Scheduling

Up to the age of 65, or shortly there after, the man in our society lives in a work-oriented and money-oriented society, with its values centered on production He spends the major portion of his day working Then he is retired With the removal of the work compulsions, he is expected to fill up his time with meaningful activities and to work out a new schedule or pattern of living In essence this scheduling problem is not unlike that faced by the infant or young child in that the retired person not only must find activities with content to occupy him but must arrange them in sequence in such a way that over a period of months or years he can return to the same elements of the pattern again and again and thus gain the psychological support that was previously given him by his work life Once an activity is patterned and assigned an approximate place in time, it becomes possible for the person to fit in other activities and thus enlarge rather than diminish his life space

For the married woman with a family, however a different set of values operates Her thinking activities, schedules, identification and social relations center in the family When the married woman finds that her children have grown up and have left home to establish their own homes she meets a problem similar to that of the man at 65 She has to develop time filling activities which will meet her personal and social needs and give her feelings of identification and worthwhileness Many of the voluntary philanthropic and social activities in our communities are carried on by women on a volunteer basis who are seeking new activity patterns to occupy their time

To gain insight into the problem, we may turn to the comprehensive studies of Friedman and Havighurst (1954) They interviewed individuals in various vocations prior to and after retirement in order to determine the meaning of work and of retirement to them and to study the adjustment of those who had retired The occupations studied were those of steelworkers, coal miners, retail salespersons, skilled craftsmen, and physicians For all these occupations work had overwhelming importance as a major axis in the person's life Adults spend more time at work than at any other

activity In very large degree work determines the income level the place a person lives the pattern of his social life and many of the relations of his wife and children Despite work's critical importance, the interviews show that its selection is seldom deliberate—more often determined by a pattern of circumstances many of which are beyond the volition of the person

For steelworkers and coal miners who are relatively unskilled work gets its main meaning from the money received with work's value as a routine to make time pass in second place For the skilled craftsmen, who enjoy their work more self respect and self expression vie as top meanings while money is in a lower position The values of work as a routine as providing association with others and as self-expression are high for the salespeople while service to others and association with people rank highest for the physicians Generally speaking, however the meaning of work as a source of self respect of interesting purposeful activity and of a service to others increases with the skill and educational level of the occupation

To steelworkers and coal miners retirement presents a major adjustment problem since the old patterns of association upon which they depend for support of the self are lost Usually they have little in the way of personality resources such as interests and skills which can be used in the free life they are expected to live after their work responsibility has ceased Neither their education which is meager, nor their experiences have prepared them for retirement Some of the coal miners who have secondary experience in farming fare better than others who lack that experience

The situation is somewhat better for retail salespersons but not strikingly so Generally speaking, they like to be with people and are disturbed at the changes retirement brings in their interpersonal relations But they are a little more likely to be resourceful in finding new activities in their leisure

Even though the skill of the craftsmen eases the problem of retirement and aids in the continuance and discovery of activities during their leisure, difficulties arise in retirement which center in the loss of their friends and companions at work

For the older physician the identification with the profession, which is more marked than in the other vocations, persists into retirement For them the extra values that inhere in their work, such as service to others prestige, and self expression, continue to be meaningful Although most of the physicians above 65 were still working on either a full or a part time basis, detailed interviewing showed that all, except a very few had reduced the amount of work done compared to their own younger years either by acquiring assistants or by reducing the number of patients A very few had given up practice entirely and were following strong hobbies

In Friedman and Havighurst's concluding chapter on "Retirement from Work to Play" some of the questions raised by retirement as a new way of life are brought out Can we afford the withdrawal of so many persons from production? If we can, how can we secure the extra-economic values (social participation, interesting experiences, creative self expression, routinization of life activity, self respect, the respect of others) that work has brought to the adult into the life of the retired person?

In view of the principle of the equivalence of work and play, how can we learn the arts of leisure and thus discover these extra economic meanings? A small study in Prairie City showed that employed persons over 65 were superior to retired persons in the intensity and scope of their leisure time activities and their ratings on personal adjustment, when just the opposite should be expected Perhaps the present generation of adults who have given more time to the arts of leisure will know better how to replace work with leisure How can we meet the inexorable trend toward leisure both in adult life and in old age?

Many current conceptions of the activities desirable for old people revolve about

what may be called the entertainment con tinuum in which the older person is thought of as being occupied with momentary ac tivities on an entertainment level While no one can deny the value and importance of entertainment, it should be clear that as we think through the problem of the rela tions between the use of energy and the time world in which the individual lives pure entertainment and many kinds of mo mentary recreational activities will in time lose their hold upon the individual and cre ate difficulties which could be avoided by a more realistic approach to the needs of the older person

Obviously this picture is affected by the social background and the cultural values of our society In some societies individuals are perfectly willing to watch the time go by but in our society with its strong em phasis upon achievement and upon striving during the major portion of the adult life the proportion of persons who fall into this classification is small We then need to think of the older individual as a collection of attitudes built over a long period which regulate the manner in which he spends his time If these attitudes have been built in a work oriented society in which idleness recreation and leisure are considered a waste of time and hence are centers about which guilt feelings develop the problem of the older person who is suddenly freed from time and space demands and has to learn to waste time rather than to use it becomes an acute one from the standpoint of emotionality and of personality

Of course in this area as in all others individual differences are large Also within any society as complex and as large as ours there are many subcultures which do not respond as strongly to attitudes which characterize the whole society Moreover studies of individuals and of subcultures ind cate that there are some persons usu ally a small proportion who are trained through childhood and adulthood to devel op attitudes toward time work and energy disposal which run opposite to those of the dominating portion of the population Enough has been said to indicate that the problem of how the person uses his time—in terms both of the content that fills time and the manner in which time is scheduled and of the relations of these outcomes to the various appetites needs and tensions within the organism—is a significant area for research

X Summary

the ordering within systems of behavior which results in greater effectiveness with less effort and (*b*) the placement of sys tems of behavior within time in such a way that time becomes filled with activity The first involves learning or achieving compe tence within a system the second involves scheduling or stabilizing between systems Both are related to age In general aging results in efficiency or economy of effort at the cost of variability or versatility

2 The human being may be viewed as an energy system of great power in which food is converted into activity under the direction of a coupled control system—the nervous system How this conversion oc curs is determined by the flow of stimula tion the transmission of the control sys tem and the power available

3 From studies on animals it seems clear that spontaneous activity increases during growth reaches a level that is main tained for a time in maturity and then de clines with age For human beings no clear answer can be given about the course of spontaneous activity because of the wide variety of motivational and cultural factors to which human action is subject But it is reasonable to suppose that after maturity there is an over all decline in the energy resources of the system

4 With development there is a stabiliza tion and ordering within and among sys tems of behavior The development of time filling activities is partly a matter of in ternal need and partly a matter of social conditioning Changes in activity occur at

transitional zones in the person's life, particularly at retirement

5 The content of learned patterns of behavior and the arrangement of such systems in time is markedly affected by the contents and demands of the culture and by the amount of power available for machines The latter have in recent years transformed many phases of living for males and females

6 Because of its continuity over time, the large amount of time it regularly takes, and its relation to other phases of life, work becomes a major nucleus of life activities *and a source of adjustment* Yet little is known about the relation between age and the functional efficiency of the person as revealed in work

7 In order to survey some of the factors involved in productivity we turned to Lehman s studies on outstanding persons because they presumably have more opportunity to control their own time and output than do persons who are under regulated work conditions Generally speaking, Lehman shows that high creativity or quality work marks early maturity, the period between 20 and 40 years, and that from 40 years onward there is decline But, in terms of quantity of output, there seems to be little change until the late sixties In many respects the curves for outstanding intellectual and cultural activities resemble those for outstanding athletic activities Lehman shows that similar relations hold in various cultural backgrounds and that in historical time the quality of performance has moved toward earlier age levels In spite of the basic similarity of the age curves obtained for a wide variety of intellectual creative, scientific, and cultural activities, analysis shows that marked differences occur in the ages at which society typically gives responsibility and recognition Whether this shows a discrepancy between ability level and social demand or depends upon the identification of ability and society's confidence in ability or upon age itself cannot be answered at the present

8 Studies of the interests of persons during the adult life indicate a high stability of interests over years While the aging person may develop new interests from time to time and while, in terms of broad areas of interest, there is some change with age, nevertheless, the data suggest stability for items, areas, and general pattern There seem to be progressive changes in the content of activities with increase in age which are revealed mainly in recreational or leisure activities

9 In our society at present, older persons at a definite age retire from their work and are faced with the necessity of developing meaningful activities that will fill the time that becomes available to them Their success in developing such activities is related to educational level, to socioeconomic or cultural status, and to their earlier experience

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XXIII

Personality Theory and Aging

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I INTRODUCTION

The purpose of this chapter is threefold to review some personality theories, to discuss their extensions to phenomena of aging, and to refer briefly to studies of aging which have some relation to these theories Since few students of personality have systematically considered phenomena of aging, and since it does not seem appropriate to elaborate one theory at the expense of others, the task of organizing and writing this chapter is difficult Generally, it has not been regarded as a goal by the present writer to extend available theories in detail where no account of the aging personality has yet been given or to readjust rigorously most of the interpretations advanced in present research for the sake of their integration into some theories What seems necessary at the present stage of our knowledge is to point out some basic concepts which have been emphasized in one or the other theory and which seem to be especially useful for future inquiries into the aging personality Before turning our attention directly to the subject matter, some brief remarks should be made about the nature of theory and some characteristics that an adequate personality theory of aging may be expected to have

On the Nature of Theory

Generally, a theory is regarded as a set of conventions which can be proved neither as true nor as false but only as *useful* or not useful Since these conventions are adaptations of the theorists and not necessarily determined by nature, the construction of a theory resembles the creations of an artist but differs with regard to the specific relevance of its content and the evidence upon which its value is judged In particular, a theory consists of a *set of postulates* minimal in number and systematically related to each other, and a set of operational or *empirical definitions* The postulates play the same role as the axioms in a purely formal system but differ from one field to another according to the purpose the theory is expected to fulfil For example a postulate in psychological gerontology might be that *associations between meaningfully related words become strengthened with increasing use and, corollary to that, with advancing age* The empirical definitions relate the concepts used in the postulates, such as the concept *association between meaningfully related words*, to measurements They reveal an isomorphism between concepts and measurements Thus an empirical definition for the context mentioned above may be the following *Scores on a synonym test are approximate measures of the associations between meaningfully related words* In developing a theory, close attention has to be paid to the various interrelations of the postulates, which give logical consistency to the theory and make inferences possible, by which new factual knowledge may be anticipated.

* The author is greatly indebted to Dr Ruth M Riegel for her assistance and suggestions

These inferences are stated as *hypotheses*, preferably as statistical null hypotheses

The ideas outlined above have been clearly expressed and extended by Deutsch (1954) in his analysis of Lewin s attitudes toward psychological theory

Lewin on the other hand emphasized that *completely* adequate scientific concepts not only required explicit operational definitions which would provide linkages to observable facts but also conceptual definitions which established the linkage between any given concept and other concepts in the system of concepts (or theory) One might go a little further and state that the possibility of an unequivocal *and* consistently repeatable operational definition of any psychological *concept* is dependent upon the state of psychological theory That is one can not give a precise statement of what is being done (i e a statement of all the *relevant* variables which *interact* with one s measurement *procedures* and the variable being measured) as one measures *intelligence* for example unless one has a theory which enables specification of the variables which may influence either intelligence in the situation of measurement or the testing procedure by which intelligence is measured [Deutsch 1954 p 188]

A theory fulfilling the requirements stated above may serve at least three important functions (1) It may incorporate all relevant empirical data into a single system and still leave room for new knowledge thus fulfilling not only aesthetic but also pragmatic aims since the increasing stock of empirical findings requires such integrations which in turn facilitates scientific progress (2) A higher level of abstraction may be attained if the theory relates descriptive information in such a way that explanations of various events become possible, generally by reducing them to the concepts used in the postulates (3) As noted above the theory may lead to inferences by which new factual knowledge may be anticipated

A review of these requirements will show that, up to the present time, hardly any personality theory will satisfy the conditions This may be due to the following reasons (1) The importance of the close interactions between theoretical concepts and measurements has not been recognized sufficiently (2) The attempts were too ambitious to describe the totality of psychic patterning at a time when too little factual knowledge was obtained Generally, one was more successful when the theorizing was restricted to narrower goals and subsystems (*e g*, to analysis of perception motor or verbal behavior, learning social communication, etc) (3) The requirements for theory construction itself have not become outlined in detail until very recently

In spite of the failure to meet the criteria the value of the early theories by no means has to be underestimated for stimulating research, integrating findings and revolutionizing traditional ways of thinking as well as for applying psychology to meet practical demands such as the care guidance and therapy of persons On the other hand the lack of theorizing about the aging personality in particular is not necessarily to be regarded as a disadvantage for psychological gerontology The rapidly increasing stock of factual knowledge as well as the modern reformulations of personality theory allow the gerontologist to avoid earlier pitfalls and to attain higher levels of abstraction than previously

Personality and Aging

Up to the present time very few attempts have been made to develop or adjust psychological theories in order to integrate and to explain changes of the aging individual Already in 1933 Miles had pointed out

increases [1933 p 118]

Different attempts have been made to relate psychological phenomena to biological factors, and others have stressed the dependency of the aging process on environmental influences (e g , on social demands and popular beliefs about the abilities of older persons) While both these approaches would yield non psychological interpretations only, a theory on personality and aging also has to take something else into consideration Instead of giving a full account of what such a theory should be concerned with (hoping that this becomes clear by presenting the various theories in the following sections), it may be sufficient to state here that such a theory has to center around the interrelations between the many inferred structural and dynamic psychological variables as well as around their dependence on biological or social components A personality theory may be regarded as a description of this network and the manifold interactions of variables Generally, the attempt is made to reduce this multitude of variables to a few basic factors A theory of the development of personality has to take into account the changes of these interrelations with increasing age

The simplest relationship subsumed under such a theory would be revealed by the study of the dependency of one psychological variable on age However, because of the properties of the age variable, already this inquiry yields serious problems Generally, age is measured on a physical, chronological time scale and not in psychological units Anderson (1958) and Welford (1958) have pointed out that psychological age changes may well occur at different rates along the chronological age scale, disease or accident may take a rapid toll of organic capacities, while experience may lead to insight which suddenly increases understanding and ability A psychological age scale should account for these "irregularities," but up to the present time, and probably because of their unknown dependency on so many other variables, no satisfying solution has been suggested Another way of accounting for these "irregularities" would be displayed by a control of individual differences, that is, by the adjustment of measures taken at different occasions on the same person before comparing and summarizing them with those of other subjects It is interesting to note that some contemporary theories center closely around the idea of an intra individual approach to personality, suggesting their usefulness to developmental and gerontological psychology

The example given above the development of one psychological variable on age, is the simplest case relevant to personality theory The more such descriptions try to approach the complexity of the personality and its development, the more variables have to be considered Thus it becomes apparent that these attempts are highly dependent on the refinement of the various research techniques Correlation methods, factor analysis, and especially the techniques of multivariate experimental designs can be conceived of as translations of these networks and interactions from personality theory into the more formal language of mathematical statistics or vice versa The theories differ, however, with regard to the content imbedded in this network and with regard to the components to which the multitude of variables becomes reduced As mentioned above, they vary here in emphasis from the attempt to relate the psychological phenomena to changes within the body to the attempt to explain the personality by its dependency on environmental variables

II The Constitution

Among the theories of personality which emphasize the interrelation between biological and psychological variables, the constitutionalists as represented by Kretschmer (1955) and Sheldon (1940, 1942) restrict their view to the outer appearance of the body and do not necessarily try to analyze their findings in terms of more refined organic variables Taken at

its face value, the frequently implied notion that the physical structure of the body is a primary determinant of behavior does not seem to be a very powerful explanatory principle and does not even resemble the phrenology of Gall, who related behavior syndromes to certain irregularities in the form of the skull He inferred, however, that these are the correlates of individual differences in the structure and development of the brain Using this simple form of the constitutional approach immediately the questions arise What determines constitution? How does it affect behavior? Does it remain stable during lifetime? Refining their approach, constitutionalists have attempted to answer these questions and have tried to relate psychological behavior not merely to bodily appearance but also to physiological and biochemical variables and have introduced genetic aspects into their theories To any student of aging who is interested in this form of reductionism, constitutional psychology may offer suggestive clues So far constitutional psychology has been primarily applied to the study of longevity and health

Kretschmer's Theory

Kretschmer (1955) one of the outstanding constitutionalists, developed a typology by relating the two major forms of mental disorder, manic depressive psychosis and schizophrenia, to characteristic patterns in the physique of men the *leptosomic* and the *pyknic* type, which he characterized in the following way (see also chap viii, Fig 6)

> [Leptosomic] a lean narrowly built man, who looks taller than he is with a skin poor in secretion and blood, with narrow shoulders, from which hang lean arms with thin muscles, and delicately boned hands, a long narrow, flat chest, on which we can count the ribs with a sharp rib angle a thin stomach [*Physique and Character*, 1925 p 21]

> [Pyknic] middle height, rounded figure a soft broad face on a short massive neck sitting between the shoulders, the magnificent fat paunch protrudes from the deep vaulted chest which broadens out toward the lower part of the body [*ibid*, p 29]

Recently, Kretschmer derived two additional types the *athletic* and *dysplastic* Since the body types alone would not yield any decisive information for psychology, Kretschmer suggested that psychotic states are directly continuous with normal behavior and that there are intermediate states in the direction toward abnormality which he calls *schizoid* and *cycloid* Based on this conviction, he generalizes from the psychotic behavior to the intermediate states and characterizes the cycloid as follows cheerful, humorous, vivid, social, friendly, softhearted, simple as well as quiet, and gloomy The schizoid is conceived as shy, irritable, unsocial, reserved humorless, honest, indifferent, and apathetic and dull

The relationship between border line normal and psychotic states could not be substantiated, however, since too many methodological difficulties arise in a study on the basis Kretschmer suggested His followers tried to relate the physique of the subjects to various psychometric variables such as tapping, color form sorting, and tracing and to tasks on association, attention and thinking Experiments of the psychogalvanic skin response, on physiological and biochemical variables, have also been performed and the precision of the body type characterizations has been increased to some extent However, as much as this theory may become specified, some ambiguity will always remain inherent because the recognition of the types has been based, as Kretschmer said, on perceptual intuitive [illegible] as to the fact that he applied it in a broad and general way instead of validating it, step by step, by means of more restricted variables

Sheldon's Theory

Kretschmer's ingenuity and brilliancy of style are contrasted in Sheldon's work (1940, 1942) by rigor and simplicity Following Kretschmer's ideas, he devised a constitutional theory of personality on sounder empirical grounds (Helwig, 1949) and described three primary components as being sufficient for a description of the human physique *endomorphy, mesomorphy,* and *ectomorphy* These components correspond roughly to Kretschmer's pyknic, athletic, and leptosomic types, the first and the last of which have been described above

Sheldon directed much effort to the development of rating scales on the three components which he used together with various physical measures for a description of the so-called *somatotype* This somatotype represents a compromise between the *phenotype* and the *morphogenotype* and is defined "as a trajectory or pathway through which the living organism will travel under standard conditions of nutrition and in the absence of grossly disturbing pathology" (1954, p 19) Analyzing data on about 46,000 men, he identified 88 different somatotypes among the theoretical possible 343 patterns (given as combinations of the three components as rated on seven point scales), which he described in his *Atlas of Men* (1954) Like Kretschmer, Sheldon tried to relate the different somatotypes to variations in personality applying again rating scales for the description of 50 traits in a study of 200 college students Evaluating the clustering of the correlated variables, he found three primary components to be sufficient for a rough description of human personality, namely *viscerotonia, somatotonia,* and *cerebrotonia* The first

correlation between the body and temperament types are given in Table 1

Hall and Lindzey (1958) pointed out four possible interpretations of the physique temperament associations First, an individual who is endowed with a particular type of physique is likely to select certain kinds of experience which are particularly effective Second, the supposed relation between physique and temperament is mediated by commonly accepted stereotypes about behavior Third, environmental influences produce particular kinds of physique and simultaneously certain behavioral tendencies Fourth, physique and temperament may be linked by the joint operation of genetic factors Sheldon, as did Kretsch-

TABLE 1*

CORRELATION BETWEEN PHYSIQUE COMPONENTS AND TEMPERAMENT COMPONENTS (200 MALE WHITE COLLEGE STUDENTS AND GRADUATES)

	Viscerotonia	Somatotonia	Cerebrotonia
Endomorphy	79	− 29	− 32
Mesomorphy		82	− 58
Ectomorphy			83

* After Sheldon (1942)

mer rejected the third interpretation and was inclined to accept the first and the last notions as explanation for the linkage between physique and temperament

The Impact of the Constitution on Aging

The applications of Sheldon's theory to the study of aging have been primarily concerned with questions of the constancy of constitution and the correlated personality characteristics Having gathered data on the physique of several thousand subjects ranging in age from 18 to 63 years, Sheldon presented age curves which differ markedly as to their peak, form, and rate of increase or decrease between the various somatotype families (Fig 1) Nevertheless, Sheldon generally maintained his opinion about a constancy of the somatotype in attributing these age differences to somato-

type variations in longevity (i e , to a selective death rate) Pointing out that it is not the somatotype itself, however, which causes shortness of life but specific organ weakness associated with it, he draws two tentative assumptions

First that when the frequency of occurrence of a somatotype is holding steady or is rising in middle age and in the sixties the indication is that this is a long lived somatotype Second, that when in addition to numerical shrinkage the weight curve (mean weight for stature) of a somatotype turns sharply downward this is an indication of biological distress, a sign that the men of that group who are surviving at all are doing so by jettisoning bodily weight [1954, p 18]

These men have been short all their lives William James Harvard philosopher who was also a doctor of medicine, was aware of it . James raised the question whether we should not *hold back* some babies during their early years by judicious underfeeding and by rigorously regulated feeding, thereby to prevent overgrowth or a too burgeoning early growth [Sheldon, 1954 p 18]

Some of Kretschmer's followers have made sophisticated suggestions for the interpretation of developmental processes Thus Schmeing (1950) and similarly Conrad (1941) have conceived constitution as a biogenetic problem, viewing the different constitutional types as developmental stages

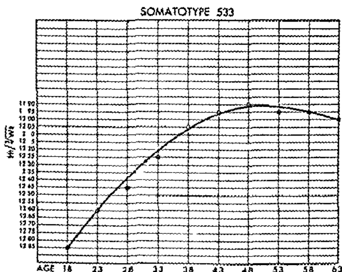


FIG 1 —Height over cubic root of weight for ten age groups of the somatotype 533 (After Sheldon, 1954)

Similar to this interpretation, differences in personality between older and younger persons may be explained Sheldon, however, as yet has made neither this point nor his notion about possible nutritional influences on the stature of a person very clear. He refers to William James's position in stating:

It is a common observation that the very long lived men in our American population tend to be short. However, the shortness is not a result of decrement of stature in old age.

through which a person passes in the course of his life Conrad differentiates between leptomorphic and pyknomorphic growth, of which the latter predominates the development during the first years of life The individuals begin to vary more and more during their development, which is generally directed toward the leptosomic physique, and tend to become fixated at different points along the range of constitutional stages Schmeing and Conrad illustrated their views in accounting for de-

velopmental changes during childhood and adolescence, however, they did not present methodologically sound data To do this would confront the researcher with the problem of controlling differences in the developmental rates between persons as well as between different periods within the life span of the single person, since it can be inferred from everyday observations on children that both these factors play an important role in the growth of the individuals Thus many questions remain unsettled, and few profound results as well as the extension of research on constitution and personality can be expected in psychological gerontology Aside from Sheldon s *Atlas of Men* and some similar reports on age changes of body forms only the studies by Ufland (1933) and Boehmig (1954) on the predominant influence of constitution and age on physical performance have come to our attention Questions on the genetic background of constitution and its correlates are discussed in Kallmann s and Kleemeier's chapters of this handbook

III The Unconscious

Influenced by scientific views on the constancy and transformability of energy theories of the unconscious have emphasized dynamic qualities of personality and its development. Especially for Freud the notion of psychic energy its display and over all constancy is closely linked with that of developmental phenomena While Freud weighted heavily the early stages of the human life, some of his followers have elaborated his concepts in order to account for personality changes during later years These as well as clinical and therapeutic extensions have contributed to a broadening of our views on individual differences between aged persons We shall turn our attention primarily to Freud s theory which he elaborated in various writings (1953) and which has been recently reviewed by Blum (1953) and by Hall and Lindzey (1954, 1958)

Freud s Theory

According to Freud, personality is the integration of three major systems the *id*, the *ego*, and the *superego* Among these, the id, the oldest province, represents inborn characteristics, instincts, and the reservoir of psychic energy The id is not able to distinguish the "true psychic reality" from subjective experiences or to tolerate tensions. When some desires arise, the id counteracts obeying the *pleasure principle*, in order to equalize the tensions The id may form either simple reflex actions or more complex responses, like nocturnal dreams, hallucinations and visions However, all these responses lead to an image of wish fulfilment only and do not produce long lasting tension reductions Freud has called these functions of the id the *primary processes* They are superseded by *secondary processes*, the development of which leads to the formation of another personality system the ego

In contrast to the id, the ego is governed by the *reality principle*, which allows for distinctions between the subjective reality of the mind and the reality of the outer world The ego represents the executive functions and has a relationship to the id like a rider has to his horse The ego originates out of the id and never becomes completely independent Its development is influenced by outer stimuli and it remains a dominant function of the ego to mediate between the id and the outer world by means of perception, memory learning and thinking The boundaries between the id and the ego are usually fluid but in disturbed persons a strong barrier may have been erected and both may counteract instead of co operate with each other While only the id releases energy, the function of the ego is to channelize this energy via secondary processes, it may delay responses and introduce intermediate steps before permitting the use of energy for some action

The third system of the personality, the superego originates out of the ego as a

result of the person's interactions with traditional values and ideals which primarily are imposed on him during his childhood and are enforced by reward and punishment Similarly as the id represents the pleasure principle and the ego the reality principle, the superego represents the *ideal, moral principle* The superego includes two subsystems the *conscience*, which internally 'punishes' the person by giving rise to guilt feelings and the *ego ideal* which rewards him with feelings of proudness and importance While the ego tries to postpone and channelize the impulses of the id the superego tries to block them on principle

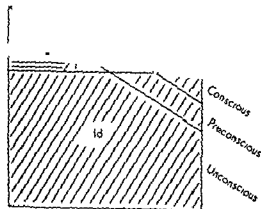


FIG 2 —Personality systems and mental qualities in psychoanalytic theory (After Dr C Bondy, University of Hamburg unpublished)

In his early publications Freud preferred a different stratification of the personality —the distinction between *unconscious, preconscious*, and *conscious* the first and last of which bear a close, although not a one-to-one, relationship to the id, respectively, to the ego and superego The relationship may be demonstrated roughly by Figure 2 Here the unconscious refers to experiences completely unknown or repressed in the course of conflicts, the preconscious, to experiences which are not yet known clearly or have been forgotten

While the extension of psychological views to the unconscious domain may be regarded as Freud's first contribution to personality theory, his account of personality as a complex energetic system is his second In most of Freud's writings the energy of the id, the *libido*, has been considered as sexual in nature Occasionally, the corresponding sexual instincts were confronted with the *ego instinct* or with the *aggression instinct* In his later publications Freud expressed a preference for a dualism, between the *life* and *death instinct*, of which the first is again closely related to sexuality and attracted most of his attention, while the latter appears to be only its metaphysical counterpart Although the instincts may be classified under these two general categories, there exists a multitude of inborn response patterns to somatic excitations which, as soon as activated tend to perform appropriate actions in order to reduce the aroused tension and to return to an internal equilibrium While the id, working without the support of the ego, cannot produce satisfying tension reductions, since it is not able to co-ordinate the urges with the outside reality, the ego may channelize the energy more perfectly The investments of energy by the ego are called *object cathexis* or *ego cathexis* (if the referent is the ego itself) and are possible only because psychic energy is *displacable*

This concept of displacement allows for a reduction of all behavior resulting from the interactions of the person with inner and outer stimulations to the instincts of the organism A great part of the energy released becomes adopted by the ego for the substitution of the undifferentiated urges of the id by objective goals, for the *identification* of images with realistic, logical, or ideational events Another part of the energy is used to prevent interference between the autistic id and the ego This investment of psychic energy is called *anti cathexis* and leads to the development of *ego defense mechanisms* which have been especially elaborated by Anna Freud (1937) Defense mechanisms may become activated by the individual when the urges of the id become too strong and/or when it cannot cope with outer stimulations. Both

may happen in situations of danger and threat Some of the most important defense mechanisms are *repression* (prevention of urges becoming conscious, this concept plays a central role in Freud's interpretations of neurosis and has been used in his early writings as a general characterization of all defense mechanisms), *rationalization* (falsification of motives for the sake of the ego and superego), *regression* (withdrawal to reactions applied successfully during earlier stages of development), *projection* (transferences of one's own motives to something or someone else), *reaction formation* (reversion of feelings into their opposites), and *sublimation* (transference of energy into culturally accepted forms, this idea is again so central to Freud's theory especially to the concept "displacement" and the ego functions, that it has not always been considered as a defense mechanism)

Finally, Freud's account of developmental processes may be regarded as his third contribution to personality theory Generally, development takes place by learning new ways of tension reduction As mentioned above, tension arises and is experienced as conflict, frustration or threat when energy cannot be immediately channelized in such a way that it becomes coordinated with inner wishes and leads to the removal of outer irritations Another source of tension is given by the physiological growth process Here Freud describes the following developmental stages, emphasizing especially the sexual behavior during early childhood oral anal phallic, and genital stages

Evaluation and Extensions of Freud's Theory

Many views elaborated by Freud have found their way into general psychology and seem to have brought about some basic changes of thinking On the other hand, it is not expected that his theory allows for the deduction of testable hypotheses in the sense mentioned before, since it hardly includes a system of precisely formulated postulates or of empirical definitions Among many implications, Freud's view on the state of the id is the most inclusive one Here, ultimately, he claims that the unconscious cannot be seized by an outside observer or by the subject himself as long as they are untrained and do not accept the complete set of suppositions making up the theory What the unconscious of an individual represents can be understood only by the psychoanalysts and, generally, has been laid down once for all in the psychoanalytic theory Under these conditions it is not surprising that all deviations from the orthodox line, like those of Adler, Jung, and the ego psychologists were conceived as overaccentuations of specific views only and that Freud's views have been accepted as dogma by some psychologists and have been as strongly opposed by many others As long as Freud restricted himself to a description of the unconscious in negative terms (e g, to an enumeration of the properties of the conscious which the unconscious *does not* possess), his approach was acceptable to many psychologists As soon as he presented however a positive description of the unconscious system and its dynamism, his theory became metaphysical, as Freud himself generally admits

The recent interest of psychoanalysts in ego functions and in the individual's development during and after childhood may be conceived as steps toward a translation of Freud's theory into the language of contemporary psychology Rapaport (1951*a*, 1951*b*) as well as Hartmann and his associates (1945*a*, 1945*b*, 1947, 1950), directed greater attention to the normal than to the disturbed person and to the effect of environmental variables than to the role of instincts Defense mechanisms are not considered as abnormal reactions but as valuable functions for the character formation, and the ego does not become differentiated from the id but is regarded as having its own origin The progress made toward conceptual refinement and the growing concern

of these authors with that psychic system which most readily lends itself for psychological observations tightened the links with empirical research and with psychology in general Different attempts to validate psychoanalytical formulations have been made (Sears 1944 Kubie, 1952 Masserman 1952 Hilgard 1953) and increasing attention has been given to systematic psychoanalytical descriptions of child development (Anna Freud *et al* 1945) Finally psychoanalytical views have been used to elaborate the theoretical background and the evaluation procedures of various diagnostic especially projective techniques which are discussed by Kuhlen (chap xxiv)

Psychoanalytical Theory and Aging

Freud made only a few remarks on the nature of psychological changes during old age most of which are related to his conception of the death instinct Leaning closely toward the philosophy of Schopenhauer he assumed that the highly unstable organic matter has the intrinsic tendency to resolve into inorganic matter and that the goal of all life is death However as mentioned before these and other formulations are hard to translate into the language of modern science It remained a task for his followers to extend his theory as well as his therapeutic method to the field of gerontology and geriatrics

These elaborations are primarily due to the work of Hamilton (1942) who distinguishes four turning points in the human life-cycle (1) termination of infancy (2) termination of childhood and beginning of adolescence (3) transition from adolescence to maturity and (4) period of change from mature to aging personality Hamilton characterized the latter period as a regression to the first two stages of development This regression is evoked by a weakening of the ego whose ability to repress disbiological and dissocial impulses decreases during later years The aging person resembles closely the adolescent in that both periods are characterized by physiological changes which may provoke difficulties for the person when called upon to meet inner and outer realities During maturity the person finds himself in a fairly stabilized physiological state has a great sense of adequacy, and tends to function more habitually and consistently than during earlier as well as later stages of development Freud himself noted that the mature person may be able to channelize the free floating energy of the id more easily than children and may be more able to demonstrate a well balanced state between the inner urging and checking forces while immature persons tend to sudden unpredictable shifts yielding large effects to little causes Similar problems arise for the aging person Atkin (1940) pointed out that aging affects most intensively the two poles of our narcissism—the genital and the brain—while the most primitive reservoirs of instinctive drives—the gastrointestinal tract the urinary tract and the smooth muscle organs—generally are the least affected ' Granting that senescence is a general biological involution one is struck by the *relative* weakening of the Ego functions in the face of Id drives only slightly abated by the decrements of aging An old balance of power is definitely dislocated (1940 p 81)

The weakening of the ego and the decrease of the energy level are undoubtedly questions of general importance however they have not yet been analyzed satisfactorily Hamilton conceives the weakening of the unconscious urges (at least during the beginning of senescence) as restricted to its highest forms the heterosexual functions and agrees with Robbins (1940) and Malamud (1941) that this decrease is strongly socially conditioned (see also Botwinick chap xxi above) Malamud warns against an overemphasis of the physiological basis of personality changes which he rather regards as the result of cumulated experiences frustration and the awareness of social limitations In contrast to this Thewlis (1924) and Henninger (1939) have

pointed to an increase in instinctual urges and libidinous drives during old age They did not relate, however, these observations to the relative greater decrease of ego strength as it has been conceived by most interpretations in Freudian terminology The differential changes of ego and id functioning and the loss of inner balance may become especially pronounced under the influence of environmental variables First, changes brought about by retirement and leading to inactivity require new orientation and adjustment Second the death of the partner, as well as of other persons the subject identified with, may bear serious problems. Third, owing to cultural stereotypes, instinctual impulses are conditioned as dangerous early in life By the weakening of the ego this social impact on the personality gives rise to strong fears, which are, according to Kardiner (1937) most profound for older persons whose life is under strong control by their children

Generally under these changed and difficult inner and outer conditions, too great demands may be made on the ego It may no longer be able to cope with instinctual urges of the id, and feelings of inferiority insecurity, and guilt, as well as of aggression and hostility toward younger persons, arise These feelings may become strength

but which become reactivated under the stress of old age (Watters 1948) Under excessive anxieties and frustration the ego may be forced to use extreme means to relieve this pressure and may be led to neurotic behavior However the person will generally organize beforehand a pattern of responses which still is to be found in the range of quite normal conduct Thus the individual may cling to reactions in which once he achieved the nearest approach to a mastery of the environment and may develop automatized and habitual patterns of behavior and rigid or conservative attitudes This form of defense may progress so far that the individual does not tolerate any change in the usual order at all He must daily do exactly the same things, sit in the same chair, eat the same food, etc , and thus may develop similar reaction patterns as have been observed among feeble minded persons and children especially in stressful situations

Since it is an important function of the ego to perceive and integrate internal and external stimuli, it is very likely that older persons, in defense against the weakening of their functions, begin to exclude stimuli from awareness This interpretation, as advanced by Weinberg (1956), calls for the concept of subception used in psychoanalytic evaluations of some perceptual phenomena Stated differently, one could say that the older person is likely to withdraw his attention from the various details of daily life which have no intrinsic bearings on his personal situation and that he becomes less concerned to store new information about outer events but more introverted more concerned, with his inner problems Weinberg points out the common observations about older persons who do not hear well but hear what they should not hear Similarly, Hamilton observed that older persons may be well able to reproduce information relevant to their inner problems, like the reproduction of experiences and dreams in psychotherapy, but less able to remember events which are more remote to their inner situations

These two forms of reaction against inner and outer threats rigidity and exclusion of stimuli, may not lead, however, to a sufficient relief of pressure Neurotic regression may take place, that is, a return to immature psychic states in which the subject once under different conditions may have found a maximum of instinctual satisfaction Hamilton views regression primarily as a sexual problem, pointing out that especially aging men experience a great number of sexual impulses which take socially and biologically forbidden directions and not infrequently lead to the accusation of exhibitionism, aggressive sexual offense against girls, or homosexual in

vitation to boys According to Hamilton the regression takes place almost exactly in the reverse order of the developmental stages outlined by Freud He observed an increase of autoerotic genital behavior especially among his patients of the seventh decade which may be due to the increasing difficulty to overcome environmental and internal obstacles for a heterosexual contact Another expression of regressive tendencies is the growing preoccupation with bodily sensations and hypochondriacal disturbances Furthermore the increased frequency of urination independent of prostatic difficulties in men the boast of the regularity and copiousness of their bowel movements (1942 p 827) and the greater enjoyment and satisfaction of food and eating are conceived by Hamilton as regression to the urethral anal and oral phases of development

All these notions have however little if any sound empirical support and one cannot avoid the feeling that the observations quoted may be stretched for the sake of the theory Kinsey s inquiries which could be relevant do not seem to yield verification a result which probably shows to what extent the foregoing formulations are based on experiences with deviant and abnormal persons However just this concern may have provided insights relevant to an application of psychoanalytic theory for the care guidance and therapy of disturbed older persons Problems of psychotherapy of older persons have been discussed in Busse s chapter xii above and also in a recent review by Rechtschaffen (1959)

IV The Self

The psychological theorizing to be discussed next is characterized (1) by its opposition to Wundt s psychophysics based on the conception of smallest psychic particles the elements (2) by its search for new methods of studying psychological phenomena and (3) by its emphasis of the uniqueness of the person and the recognition of personality as a psychological unit built up by the accumulation of experience Initiated by Dilthey s and Spranger s *geisteswissenschaftliche* or *verstehende* psychology it was argued that the experimental investigations of psychophysics are meaningless for an understanding of human beings since there exists an essential difference between functions thus investigated and higher psychological processes which can be understood only by the sympathetic act of *verstehen* by grasping events as fraught with significance in relation to a totality (Allport 1957 p 9) Since in this school totality of an individual refers primarily to his system of values meanings and intentions one must locate any single act within the personal value context of the individual s life

After initiation by the *geisteswissenschaftliche* psychology at least three diverging approaches to the individual personality may be distinguished The first originated from psychoanalytical theory and gave special emphasis to the individual s dependency on social conditions The second may be viewed as a translation of the Gestalt concept into personality theory which is also expressed by the interest in the relatedness between psychological and physiological events The third is characterized by its search for appropriate methods of studying the uniqueness of the individual While all these contributions are

ual differences in rate and direction of developmental processes

Individual Psychological Theory

During the early development of psychoanalytic theory Alfred Adler (1912 1920) broke away from Freud over the issue of sexuality Emphasizing that personality is to a high degree motivated and shaped by social urges Adler minimized the importance of biological forces and their satisfaction and conceived inborn potentialities

as general dispositions only rather than as specific drives or traits Society helps to actualize these potentialities, and the well developed individual in turn helps to further the aims of the society While for Freud the person is passively subject to his environment, and the psychological processes occur almost uncontrollably for the individual, Adler suggested the possibility of guiding one's own life—to plan for future actions and to strive consciously for highest self esteem According to Ansbacher and Ansbacher (1956), who recently systematized Adler's theory, all psychological processes are organized with reference to a goal, as a drama is constructed from the beginning with the final view Generally, this self-consistent organization, the *style of life*, becomes established early during life and is acquired by setting and striving toward a *fictional goal* All objective determiners, such as biological factors and past history, as well as the individual's opinion of himself and his interpretations of the world, his *apperceptive schema*, become relative to the goal are functional to his style of life, and influence in turn every psychological process The fictional goal is only "dimly envisaged" and largely unknown to the individual The unknown part of the goal represents for Adler the unconscious domain of the personality, which thus does not become a separate entity but is merely viewed as that part of the subject's striving which he does not understand Sometimes an individual may have only a small chance to attain his goal and the continuous feeling of unsuccessfulness will give him inferiority feelings and may seriously disturb his personality However, the person has always a chance to change or to use other, more successful, approaches, which are more likely to give him a feeling of social acceptance and superiority and satisfy his innate social interests

This idealistic and teleological optimism of Adler's theory lies close to the thinking of Stern but is especially related to the concept of self actualization proposed by Aristotle as well as by Jung, Goldstein, Rogers, and others Among the psychologists who are closely associated with Adler in emphasizing the impact of social variables on the personality organization, Karen Horney (1937, 1950), Fromm (1947), and Sullivan (1953) have to be mentioned Horney places still more weight than Adler on the social interactions, particularly on those occurring during late adolescence and adulthood within the intimate family setting, and she rejects Freud's strong emphasis on early childhood for shaping the personality Fromm discusses the social influences on the individual in a broader sense, including the complex set of the cultural background Sullivan defines more clearly his propositions and the inference to be drawn, and his theory may thus lend itself more readily for application to empirical research in gerontology

However, Adler also made related suggestions stressing especially some exogenous factors which may cause emotional and mental disturbance in later life For Adler the period of old age is characterized by strong inferiority feelings which often have their roots in the past history of the subject, brought about however by signs of impotence or feelings of intellectual or physical insufficiency as well as by outside factors like the dissolution of the family, financial losses, or the relief from office and honors

> The real position of aging people in our society is severely threatened because the value of work is almost decisive for the evaluation of
>
> But just the reverse happens in our society, we give old people no opportunity for continued self expression [Ansbacher and Ansbacher, 1956 pp 444–45]

Aside from these interpretations and because of its lack of specificity, there seem to be few possibilities, however, of adopting the concepts proposed in these theories to research on psychological aspects of aging

The Organismic View

Organismic theory as well as personology may be regarded as translations of the Gestalt principle to personality theory and are characterized by the view that personality is something over and above the sum of single elements and that it is meaningful to study separate units only in the context of the whole personality Inherent to many systems of philosophical idealism the organismic view has been rediscovered for biological science by Meyer and transferred to psychology by Goldstein (1934) Werner (1926) Angyal (1941) and others, while the development of personology is primarily due to the work of Murray (1938, Murray and Kluckhohn 1953) Murray emphasized more clearly than many other theorists the *organic totality* of personality pointing out that any behavioral function has to be accompanied by physiological processes which almost exclusively will have their locus in the brain the seat of the personality Furthermore personality has to be analyzed according to Murray in its environmental imbeddedness and in its total expansion over time (i e any behavior at a given moment must to some degree depend on past development) Significant for any developmental analysis Murray differentiated three units of time expansion proceedings serials and durances *Proceedings* are the shortest time intervals of any behavioral sequence They are determined by an initiation and the completion of a dynamically significant pattern of behavior and represent some subject object or subject subject interactions In addition to that ' a directionally organized intermittent succession of proceedings may be called a *serial* Thus a serial (such as friendship a marriage a career in business) is a relatively long functional unit which can be formulated only roughly (1951 p 272) Finally the term *durance* denotes a temporal and functional unit (such as childhood adolescence old age) of still greater complexity which embraces countless proceedings as well as various serials

Defining these units only generally and giving little attention to structural components of personality, Murray is much more detailed in specifying dynamic variables Here his interests center around the concept of need which ' is a construct (a convenient fiction or hypothetical concept) which stands for a force in the brain region a force which organizes perception, apperception intellection, conation and action in such a way as to transform in a certain direction an existing, unsatisfying situation (1938 p 123) Murray has defined twenty different needs such as *n* Achievement *n* Aggression, *n* Dependence *n* Harm avoidance, *n* Sex, *n* Understandings etc the first of which has become elaborated by the studies of McClelland and his associates (1953) applying an abbreviated form of Murray s Thematic Apperception Test (1943) Murray's attempt may be regarded as a reformulation of McDougall's (1908) system of *instincts* While the need denotes only a general tendency of the organism which calls for satisfaction the instincts are organized and directed toward concrete objects or goals and represent systems of means which will help to attain these goals Murray also shares with McDougall the use of the concept of *sentiment,* which denotes a tendency of the individual to respond with positive or negative affects to certain objects

Closely akin to Murray's emphasis of the co-ordination between physiological and psychological processes is the organismic view of Goldstein (1934), who together with Scheerer (1941) and Gelb (1920), investigated the effect of brain injury on personality Similar, also, to Murray is Goldstein s disinterest in fixed personality traits Here his view resembles the figure ground notion of Gestalt psychology in pointing out that there exists a continuous alteration with respect to which "part ' of the organism stands in the foreground Being determined by the demands and the tasks of a given situation the individual has to cope with changes in the environment and has to equalize the changes induced in order to maintain its constancy and to 'actualize" itself

The Intra individual Approach

While personology, as well as organismic and individual psychology, did not lead to any original methodological contribution, serious attempts in this direction have been made by some of the psychologists to be discussed next Following his early claim for a differential psychology in which the variation rather than the average of char acteristics is at the center of interest, Stern (1921) distinguished between inter and intra individual variability, the former referring to differences between persons, the latter denoting changes within the single person Interindividual comparisons are important for the evaluation of a person s abilities in comparison with the group However, if one is interested in a diagnosis of the unique personality structure of a subject, one needs to view the characteris tics within the context of his personality only Pointing out this difference, Stern did not succeed in developing or suggesting empirical methods of studying the single individual While he opened the way for the application of various measurements in psychology, he tended to restrict their use to the group centered approach and de veloped his personalistic theory (1935) on interpretations similar to those of the *geisteswissenschaftliche* psychology

Following Stern and generally Euro pean tradition, Allport s (1937) approach is characterized by an emphasis on the uniqueness of the individual the conscious ness of his motives, and the intimate unity of the *structural and dynamic components* of personality These views are reflected in his use of the concept *trait* as well as in his notion of the *functional autonomy of mo tives,* both derived from observations of

[illegible]

(peculiar to the individual) with the ca pacity to render many stimuli functionally equivalent, and to initiate and guide con sistent (equivalent) forms of adaptive and expressive behavior ' (1937, p 295) A trait represents a dynamic disposition which comprises several *habits* and is of higher generality than an *attitude,* which mostly refers to specific objects Traits are unique because persons are exposed to different environmental influences during their lives, traits are open to measurement, however, *because of some communality due to cul tural,* regional, or other homogeneity be tween the persons The concept of func tional autonomy denotes that an activity which has been carried out for some distinct purpose and time may be continued for its *own sake after the goal has been reached* The means to acquire a goal might become a goal in themselves just as the soldier's activities during a war may become a goal in themselves expressed in an unrestrained continuation of aggression However, the notion that motives may develop to func tional autonomy does not necessarily imply a close linkage between the person and his past On the contrary it shows how the individual may always be able to attain new and independent inner states and to divorce more and more from his biological origin and his striving toward drive sat isfaction

This view, as well as his notion of a discontinuity between abnormal and nor mal man and animal child and adult be havior reflects Allport s divergence from psychoanalytical theory Basing his theory on an analysis of the normal, mature man (e g, on an analysis of a phase in life characterized by consciousness and antici pation and planning for the future), he states

> The principle of functional autonomy holds (1) that motives are contemporary that whatever drives must drive now that the goal of a motive is not bound functionally to its his torical origins or to early goals but to present goals only, (2) that the character of goals alters so radically from infancy to maturity that we may speak of adult motives as supplanting the motives of infancy, (3) that the maturity of personality is measured by the degree of func tional autonomy its motives have achieved even though in every personality there are archaisms (infantilisms, regressions reflex re-

sponses) still the cultivated and socialized individual shows maturity to the extent he has overcome early forms of motivation [1940 p 545]

Having discussed Allport s work in some detail we could equally well direct attention to European psychologists like Lersch (1954) and Thomae (1951) among whom the latter has become concerned with problems of aging (1957) Since however these theories have been derived more or less in isolation from the interactions and the fast development of Anglo-American psychology we referred in more detail to Allport who has had a more intimate influence on ome of the recent empirical and theoretical considerations Allport emphasized that the mature person has made extensions of his self and has not tied his life to a narrow set of duties but finds enjoyment in a variety of activities In order to understand a mature person we have necessarily to secure information about these activities goals and values as Allport and Vernon (1931) have done in measuring the value preferences of persons with a scale related to a typological classification suggested by Spranger However this study as well as some others has not been conceived as an original attempt to characterize the single personality structure Aside from an analysis of life records and some studies on the stability of personality characteristics the work of Baldwin (1942 1950) a student of Allport is clearly pointing in this direction Baldwin studied the personality structure of single individuals by analyzing collections of letters and literary productions Further systematizations and methodological refinements of such an approach are due to Stephenson (1953) Rogers (1951) and Rogers and Dymond (1954) In spite of some still unsettled problems the basic idea of this approach must be regarded as a genuine solution of the old quarrel raised by the *geisteswissenschaftliche* psychology, based on Descartes s dualistic philosophy and formulated in such phrases as ' one may *explain* nature but has to *understand* man ' or in the confrontation of 'nomothetic" versus "idiographic" approaches The suggestion that we can equally well derive laws about single persons became trivial as soon as it was recognized that we simply have to obtain a set or sets of measurements taken at different occasions from the same person Applying systematically this approach Rogers was able to outline a personality theory which in contrast to most other attempts, always remained firmly tied to its empirical basis

Rogers (1951) and Rogers and Dymond (1954) derived a system of propositions for which the total individual the *organism* and the totality of experiences the *phenomenal field* are fundamental concepts As a result of interactions with the environment the organism gradually differentiates a portion of the continuously changing phenomenal field as his *self* which is characterized by Rogers as an organized but fluid conceptual pattern of perceptions The person strives to integrate every perceptual experience into the structural system of his self Values may become attached to the experiences and thus also to the self They however are never merely introjected to the person but converged by his own perception in a way which is consistent with his concept of self Other experiences may *not* become integrated and are either ignored because their relationship to the self is not perceived or denied and distorted if they are inconsistent with the concept of self Maladjustment is regarded by Rogers as a state in which a significant number of experiences have been handled in this way and accordingly a discrepancy has been developed between the experiences relevant for the organism and those which became integrated into the structure of the self

Since the *self* plays such an important role in Rogers theory (he does not differentiate any other distinct subsystem of the personality) it is not surprising that the verbal reports of the person studied are regarded as the best although not the only source of information for an analysis of his personality Every external frame of refer

ence, like evaluation schemes for observers, test methods, etc, from which inferences about the personality may be drawn, are viewed as less valid for this analysis Rogers and his associates have used subjects' observations of the self as elicited by questionnaires and check lists in order to gain information on the concept of the self In applying these instruments repeatedly during therapy and asking the subjects to describe how they are (real self), how they want to be (ideal self), and how other people may think they are, Rogers demonstrated that therapeutic success is reflected by the degree with which these different forms of self perception converge toward each other during the course of the treatment

Related Studies on Aging

First, many studies of aging could be related to the theories outlined although it can hardly be expected that they will directly verify conclusions or predictions derived This failure is of disadvantage for the theories as well as for the studies which have to be characterized in general by their lack of interrelatedness and inconsistencies of conceptualizations As mentioned before, Adler, Karen Horney, Fromm, and Sullivan have stressed in varying degrees the impact of social variables on personality and personality development and a great number of studies discussed by Kuhlen (chap xxiv) as well as by Jones (chap xi) in this *Handbook* (see also Riegel 1958c) have been conducted on the effect of such variables as (1) professional and educational status (2) institutionalization, and (3) retirement on the aging personality Not all these variables can be viewed, of course, as exclusively social determinants, since they are again dependent on inner, psychological variables, a notion quite congruent with the theories mentioned above

Second, organismic theory as well as personology have been applied by many nonpsychoanalytical oriented psychiatrists in their interpretations of aging processes as well as in those investigations in which the interrelationship between various psychological and biological variables has been studied Busse, Barnes, Silverman, and their associates have reported such investigations and have compared various clinical data (medical history, psychiatric evaluations, physical and neurological examinations, etc), psychological data (Wechsler, Rorschach, Thematic Apperception tests, etc), and the social history of the individuals ("Your Activities and Attitudes") Since Busse discusses these studies in chapter xii of this *Handbook*, it may be sufficient here to refer to an investigation by Margaret Thaler (1957) on the relationship among Wechsler, Weigl, and Rorschach tests, EEG findings, and "abstract" and "concrete" behavior Both the latter concepts have been proposed by Goldstein, to whom a concrete attitude consists in a simple recognition which lacks the realization of any meanings of background of events the abstract behavior implies the selection of essential features, the inferring of category meanings, and the ability to shift back and forth from abstract to concrete attitudes as the task requires Like Hopkins and Post (1955), Margaret Thaler observed in a group of 116 normal volunteers a marked change toward concrete behavior above the age of 60 years and inferred that they might also be concrete in other ways "They may try to adjust by sheer attempts to recognize aspects of their environment and be unable to form inferences and conceptually interpret what is going on around them These aged persons may feel there is only one meaning to a situation, and hence have the 'rigidity' so often attributed to the elderly" (1957, p 408) While the author could, furthermore, detect significant relations between Wechsler and Weigl performance as well as between associative impoverishment on the Rorschach and concrete performance on the Weigl Test, she was unable to find a relationship between age and EEG classification

Third while Rogers view resembles in many aspects the views of Goldstein Murray Adler and others his idea of accumulating data on single subjects by systematic replications of the inquiries must be viewed as a genuine contribution to personality research Several more or less rigorous attempts have been made to study the aging person in his individuality Charlotte Buhler (1933 1935) emphasized the use of biographical analyses for developmental studies and confronted the biological aspect of aging as analyzed by testing and experimental procedures with an experiential (*Erlebnis*) and productivity (*Werk*) aspect While she used a *geisteswissenschaftlichen* approach of sympathetic understanding to evaluate the subjective experience changes she referred to more objective data like publication and production records in order to analyze the creative achievements and their changes during the life span Buhler s study was based on the analysis of 206 life histories of eminent men and on anamnestic inquiries of 50 aged persons The third aspect of her analysis the productivity (*Werk*) aspect has been investigated by a great number of other writers among whom particularly Lehman (1953) became distinguished for the extensiveness and precision of his studies One should note however that in his approach (which has been discussed in chap xxii of this *Handbook*) the data on the life span of single individuals have not been kept completely separate but have been averaged again according to the different fields of activities

The same holds true for studies on the intellectual deterioration of older subjects based on the Babcock Gilbert hypothesis concerning the stability of vocabulary scores According to this approach one may use the vocabulary for estimating the original intellectual capacity as well as the deterioration of a person by comparing his results in various tasks with his vocabulary achievement. However, this method can be viewed as a quasi intra individual approach only since the comparison of the achievements is dependent on prior inter individual transformations of the test scales and since in general, the hypothesis about the stability of the vocabulary has also been tested by group comparisons only Aside from the method proposed by Harriet Babcock (1930) and applied by Jeanne Gilbert (1935) other attempts have been made to use differential test comparisons and profile interpretations in order to draw special inferences not only about the intellectual functioning but about the personality of older individuals Since however these investigations have been discussed in H E Jones s chapter of this *Handbook* it may be sufficient to state that in spite of much research there is still doubt as to the validity and comparability of the estimates derived

A genuine contribution to the intra individual study of the aging personality has been published recently by Madorah Smith (1952 1957) In the first of her investigations the author obtained personality ratings on six subjects over an age span of 50 years and analyzed the stability of these traits Still of greater interest is her study of five 2000 word samples drawn from letters which had been written by a woman over a period from 40 to 89 years Classifying the words and clauses according to various categories the author presents the corresponding age curves as well as data on some coefficients proposed by Baker Dollard Mowrer and Mann and others for personality research She also made suggestions as inferred from the content of the letters about the influence of environmental (arrival of visitors death of a sister etc) and organismic variables (health) on the achievements—an approach which under better experimental control could relate the descriptive information obtained in various ways to more complex personality interpretations

Finally some attention has to be given to studies directly related to Rogers personality theory As mentioned before Rogers pointed out that when all of the ways in which the individual perceives himself—all perceptions of himself in relation to oth

ers—are accepted into the organized conscious concept of the self, then this achievement is accompanied by feelings of comfort and freedom from tension which are experiences as psychological adjustment" (1947, p 364) Since many of the serious difficulties arising *during later years and provoked* by retirement, loss of a partner, or property, decrease in abilities or health, etc, are likely to be correlated with changes in the concept of the self in general or with increasing divergencies between the specific forms of its evaluation, many studies of aging have used the concept of adjustment in almost the same way as defined by Rogers This is especially true for the investigations of Ruth Albrecht, Ruth Cavan, Havighurst, and others to be discussed in our section on role theory, that is, in the context of a theory which has, at least in the formulations given by Sarbin (1954), close links with Rogers' views Aside from these investigations a number of studies have to be mentioned in which older subjects were questioned about their own notions about how and when aging begins Giese (1928) made an inquiry of this kind on 350 persons and reported that bodily disturbances were mentioned more often than psychological problems as symptoms for aging Among the latter, signs of emotional indolence outweighted by far those of intellectual deterioration Tuckman and Lorge (1954*b*) asked aged persons about their happiness in the different phases of life as well as for a self classification according to age groups (1954*a*) Evelyne Mason (1954*a*, 1954*b*) employed a self concept questionnaire and applied methods which indicated whether or not the subject had any clear conception of who he is as an individual and what his positive or negative affectively toned reactions are toward figures with which he most readily identifies Institutionalized persons revealed more negative views about themselves as compared with non institutionalized subjects While both groups did not differ from each other in their expression of happiness and their views about their present abilities, they were found to be inferior in comparison with younger persons

V The Inner Personal Structure

The class of phenomena to be discussed in this section constitutes the core of any personality theory as well as being the "missing link" of behavioral analysis Although numerous speculative attempts toward its analysis exist, most of the empirical approaches have been restricted to specific but important aspects of the inner personal structure, not until recently have these approaches been extended to embrace the whole class of relevant phenomena Since perceptual or cognitive theories constitute such attempts it is not surprising that the majority of the studies of aging could be related to this section of our chapter, although the investigators themselves hardly intended any contribution to personality theory and did not arrange their experiments accordingly The student of aging is referred especially to this section because these theories open the way for rigorous experimental approaches to personality whereby the important concept of structure may be analyzed under developmental aspects

Conation (Motivation)

Gestalt psychologists disregarded distinctions between reality versus illusion and sensation versus image and minimized the role of antecedent experiences every experience carries its own validation Furthermore, they pointed out that there exists no barrier between higher and lower psychological functions or between organic and inorganic events and that any perceived (psychic) structure should find a structural (physical) counterpart in the brain processes Since the phenomenal field has appearance only, whereas the world of physics has been abstracted from the phenomenal appearance and represents reality, this hypothesis of a real isomorphism furnishes, *for Gestalt psychologists*, a genuine link of objectivity In their attempts to

confirm this hypothesis, Gestalt psychologists have become closely connected with neurophysiology and anatomy but at the same time this interest seems to have hindered them from studying the influence of personality variables on the perceptual processes and has led critics to remark that the perceiver or Gestalter has been left out of their analyses

Since it is perception which links the organism to the outer world its study seems to be most appropriate for an analysis of the inner personal determinants of behavior The strictly sensory oriented research in this field concerns perceptual processes in which a direct relationship with no ambiguity exists between the stimulus and the response (see Weiss chap xv above) However in life situations this is hardly ever the case and thus the person not only may have to make selections in order to perceive but also may have to interpret the perceived situations It is not surprising that perception of ambiguous material has for a long time been an open field for clinicians and personality theorists however not until recently has the influence of personality and social variables on perception as well as on recall (memory) been investigated systematically and with refined methods This movement the ' New Look approach to perception has attracted many psychologists among them Bruner, Erikson, Howes, Lazarus McGinnies, Postman, and Solomon The effect of socioeconomic status, personal values success and failure, reward and punishment deprivation, social habits, etc , has been investigated generally, in presenting unambiguous stimuli tachistoscopically to the subjects Most of the manipulated variables influenced the recognition threshold but they also revealed *significant individual variations*—a variable thus far seldom considered Many of the research results are integrated in the hypothesis theory of Bruner (1951), which states that the perception or recognition of stimuli is preceded by more or less distinct formulations of hypotheses The strength of these hypotheses increases (1) the more frequently a hypothesis has been confirmed previously, (2) the fewer hypotheses there are available, (3) the more a hypothesis integrates different phenomena (4) the more promising the verification of a hypothesis is, and (5) the more social factors are used as cues for the development and confirmation of hypothesis

In the experiments mentioned above, operationally defined personality variables have been introduced which reflect some form of inner urge and are denoted as instincts, drives, motives, needs, attitudes, or interests These variables have been traditionally characterized by two attributes direction and force All further characterizations differ, however, as to the number, the complexity, the specificity of direction and the relation to some physiological or bodily origin A psychological system in which these incentives play a dominant role has been called ' dynamic," whereby ' dynamic' denotes either the interdependency of the variables, that is, a system where a change of any subpart changes the state of any other subpart (Lewin), or, more generally, the energetic quality of the system (Freud) It is the latter notion which is expressed by most so called dynamic personality theories, which differ, however, in their views on the source of the incentive Some psychologists, like Freud, generally expressed their preference for a monomotive theory in which the manifold of observed motives is compressed into a single source

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Recently, as previously [illegible] ray has shown some inclination toward the latter conception in discussing a set of twenty basic needs Avoiding speculative interpretations, Murray has taken precaution to draw his inferences from observable events and stresses the view that needs are merely constructs which can be inferred on the basis of "(1) the effect or end result of the behavior, (2) the particular pattern or mode of behavior involved, (3) the selective attention and response to a particular class of stimulus objects, (4) the ex

pression of a particular emotion or affect, and (5) the expression of satisfaction when a particular effect is achieved or disappointment when the effect is not achieved" (1938, p 24) However, in spite of these refinements, much remains to be done with regard to conceptualization and measurement techniques Moreover, Maslow (1955) and Murray (1938) have suggested that motivation should be considered not only as a process of tension and tension reduction but also as a source of original and spontaneous tension production which leads to active development instead of passive adjustment to outer and inner irritations It remains, however, a question as to what extent this concept of *growth motivation* leads to fruitful elaborations, especially in the psychology of development and aging, and how far it merely adds new difficulties to the entangled discussion

Affection (Emotion)

From the behavioristic point of view the concept "conation" (motivation) has to be considered as a construct, since it denotes intermediate psychological processes which have been inferred only from stimulus response interactions Following the traditional philosophical distinction, two other

ception, learning, retention, and thinking, and few reliable results have been obtained on the role of conative and affective components This may be due to a lack of conceptualization While cognitive functions have been the object of various analyses for a long time, conative and affective processes have not been discussed in any rigorous manner In general, emotions are denoted as consistent but fluent inner states of the individual which are frequently related to bodily or physiological conditions (Reymert, 1950, see also Botwinick, chap xxi, above) Following the views of experiential psychology and philosophy, emotions have been characterized as a metaphysical counterpart to cognition and thus as *not* goal directed and as *unstructured*

The concept "emotion" has been introduced into psychological experimentation with reference to such physiological measurements as metabolic rate blood pressure, galvanic skin response perspiration respiration salivation etc These have been discussed in detail by Lindsley (1951) and seem to make operational definitions of emotions easier than those of conative factors The relationship between emotion and physiological variables was expressed early in the theory of James and Lange who stated that the stimuli received are reported to the cortex which elicits responses in the viscera as well as in the muscles, the first evoking emotions and feelings in the subjects Cannon (1927) and Bard (1934) modified this theory They still relate the emotions to visceral changes which are, however, released by the thalamus, an organ which functions as a relay station between the cortex and the receptor organs Later elaborations and studies have led to the development of an activation theory of emotions outlined by Lindsley (1951) in which certain interactions between the cerebral cortex and subcortical structures became more specified Finally, reference should be made to Young (1943), who, in opposition to Leeper (1948), pointed out that responses may become organized as well as disorganized by emotions and who emphasized the emotional qualities of attitudes Young regards the attitude as a long lasting and stable prior condition to emotional or non emotional responses Thus emotions and attitudes (and one may also say motivation) are clearly separated, but the arousal of the first is dependent on the latter In order to study emotions, we need also to know something about the attitudes acquired during the past and consequently something about the relationship between these past experiences and the present situation, a view very significant for the psychology of development and aging

Cognition

Relying on introspective techniques cognitive processes have been investigated by the Wurzburg School and characterized as including "all the means whereby the individual represents anything to himself or uses these representations as a means of guiding his behavior" (Leeper 1951 p 736) Cognition was then studied by Gestalt psychologists but in a restricted way namely restricted to the perception of structural stimulus qualities and their possible correlates in the brain Adams (1931) influenced by Lewin extended this view and regarded processes like cognition as dependent on (1) the external physical environment (2) the internal physiological environment and (3) neural tracts of past experiences Another extension of Gestalt psychological views has been elaborated by Tolman (1932) whose cognitive theory has been traditionally confronted with stimulus response theories

One reason for this categorization is related to Tolman's distinction between molar and molecular approaches to psychology and his inclination toward the first (i e toward an analysis of complex behavior which however does not need to become an end in itself but may eventually become reduced to configurations of more elementary units) While stimulus response theory attempts to analyze behavior in terms of associative bonds between outside stimuli and overt reactions cognitive theory is primarily concerned with the question of how the stimuli (signs) become perceptually organized (significate) by the subjects This concern which again reveals the Gestalt psychological background of cognitive theory is also expressed by Tolman's interpretation of behavior in terms of its goal and purpose Scheerer states that cognition is the "initial orientation toward a goal-object in terms of distance, direction and valence character and as a reflection of a means-object or path in terms of its suitability for reaching the goal Cognition is further definable as the behavior change upon attaining the goal and as the variation of behavior if the goal does not prove to have the initially perceived valence" (1954, p 94) Whereas for stimulus response theories, behavior is determined by drive and environmental stimuli and by the acquisition of movement patterns, for Tolman it is determined by perceiving means or signs to a goal, by developing "cognitive maps," and by learning behavior patterns.

The denotation of Tolman's interpretations as cognitive theory is, however, somewhat misleading, since this term has been traditionally confronted with the concepts "conation" and "affection," which should be equally well considered as variables mediating between stimuli and responses Like Scheerer, Tolman has hardly restricted the meaning of cognition in this sense According to Scheerer, cognition is not determined by the stimulus alone but always in connection with the organizational and other response dispositions characteristic of the person Tolman's view is revealed by concepts, such as means end readiness, which denote the integrity of cognitive, conative, and affective aspects On the other hand, he has specified some variables which influence cognitive processes heredity, age, previous training, and special endocrine drug or vitamin conditions (1938) Among these, the variables age and previous training are of especial impact for gerontological research However, since Tolman does not seem to have elaborated these determinants of individual differences in detail, it is difficult to estimate the relative importance and the relationship of these variables to each other

Structure

While early Gestalt psychologists restricted their investigations to the study of autochtoneous variables as determinants of perception and cognition, later psychological work has been concerned with the influence of inner personal factors such as emotions and motivations Generally, the results relevant for personality theory have

stressed the utility of abandoning completely these concepts, traditionally used in philosophy and psychology What seems rather necessary is the recognition of the role of accumulated past experiences for the analysis of any intervening psychic process, that is, the use of a concept which makes the question how motivation or emotion influence perception or cognition unnecessary and incomplete (Ruth Riegel, 1956) To answer this question, we have to refer either to past experiences stored as some organized, structural arrangements by the person or to some immediate bodily states, the representation of which may depend, however, on learning and past experiences Thus the analysis of the individual's experience structure may be very important in accounting for individual differences in processes like perception and cognition and for differences in emotions and motivations Among the proponents of this approach, Adams (1953) denoted the totality of cognitive, conative, and affective components which refer to objects of experience as *sentiments* and derived a set of propositions about their structural relatedness Adams did not submit his propositions to empirical testing, however, his notion about the sentiment structure has many points in common with a theoretical model outlined by Cattell (1950) and, similarly, by Eysenck (1953), who made comprehensive attempts to integrate the major findings of factor analysis as well as general knowledge about personality

Cattell classified traits, which are the most important concepts in his theory according to different principles, such as common versus unique, surface versus source, environment mold versus constitutional, dynamic versus ability versus temperament traits The first two distinctions are most clearly dependent on his method of approach common traits represent some part of the variance which is shared by all individuals with similar experiences, while unique traits are more or less related to single individuals Surface traits are the outcome of interactions between different source traits which are more stable and reflect "real structural influences underlying personality" (1950, p 27) Of greater theoretical importance than these distinctions is Cattell's concern with dynamic ability and temperament traits, which are again subdivided according to their dependency on environmental or constitutional influences In contrast to most other factor analytical approaches to personality, Cattell has especially elaborated the role of dynamic traits Based primarily on the analysis of life records and personality ratings, he confronts the constitutional, dynamic source traits (ergs) with the environment mold, dynamic source traits (metaergs) The first are closely related to biological processes as well as to McDougall s notion of instincts and are more or less determined at birth, while the environment mold dynamic source traits (metaergs) are modifiable during the individual's development This category includes such components as interests attitudes, and sentiments, which differ from one another according to their stability and to the time of their development The latter, the sentiments, are derived early during life and are the most permanent they are characterized as combinations of cognitive, conative and affective components and are thus highly congruent with the same concept used by McDougall and by Adams The interactions among attitudes, sentiments, and ergs (used here as a general term for the dynamic source traits irrespective of their modifiability) are represented in Figure 3

Cattell carefully points out that his conclusions are by no means all derived from factor analytical findings His efforts have, however, at least shown that the study of structures may be extended to include dynamic variables and that, finally, it may become possible to describe these forces in terms of structural changes As mentioned before, Lewin inferred psychic forces from the interdependency of various subparts of a psychic system, while Freud conceived them in analogy to physical energy Examining these views, we have to note that

in classical physics also energy is an inferred concept namely, inferred from the observation of a mass and its locations at various times in a movement process The concept of energy (kinetic energy) used here differs of course from those concepts which may become applied in psychology since it has been expressed in a mathematical formulation and related to measurement procedures However this analogy shows that in psychology also it should be possible to infer and comprehend psychic energy from a set of observed momentaneous states namely in evaluating the proc

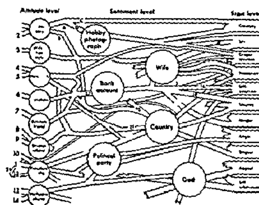


Fig 3 —Fragment of a dynamic lattice showing attitude subsidation on sentiment structure and ergic goals (After Cattell 1950)

ess by which these states convert into each other Lewin and his students have done that and they have inferred the strength of dynamic variables by observing the changes in the group structure In personality research inner forces have been most precisely studied by gathering information on interests and attitudes of persons both of which represent overt expressions of directed impulses However what may be much more important than obtaining a cross sectional collection of potential goals toward which a person may or may not later strive is the information about the extent to which the person is actually releasing his energy by continuously changing his inner personal structure It is exactly this approach which characterizes the efforts of learning theory, although there the process of "changing structures' has not become necessarily related to the concept of psychic energy Before we refer to these theories, we shall review some studies on cognitive conative and structural aspects of the aging personality

Related Studies on Aging

While relatively few psychologists investigated the impact of motivational and emotional components on the aging personality (see Botwinick, chap xxi, above) the great majority of studies was concerned with cognitive functioning The investigations discussed by Weiss (chap xv) and Braun (chap xvi) on sensation and perception by Jones (chap xx) on intelligence and problem solving, by Jerome (chap xix) on learning, and by Welford (chap xvii) on psychomotor performance need to be mentioned in this context Many studies which are reported here have been arranged in such a way as to answer specific questions derived from earlier investigations and thus an increasingly finer network of variables has been used to describe the cognitive structure in old age Similar attempts have been made in submitting the various subparts of test batteries to factor analytical treatment and we shall refer to these studies as examples for an inquiry into some cognitive components of personality structure and its development over the age span

Balinsky (1941) used for his factor analysis the data on the first standardization of the Wechsler Intelligence Test (1944), which he divided into six age groups 9, 12 15, 25–29, 35–44, and 50–59 years Using the Thurstone Centroid Method, he extracted a number of factors which contributed quite different proportions to the results of the various age groups, and he came to the following conclusions "(1) that the same factors do not always appear at each age level, (2) that the verbal and performance factors are most consistent, (3) that the memory fac

tor appears only in ages 25 to 29 and 35 to 44, (4) that a *g* factor is found for the nine year age group, then is apparently submerged and appears again, but not as definitely at age 50 to 59' (1941, p 230) Thus Balinsky's results revealed a tendency toward greater specialization from age 9 to ages 25–29 and "thereafter an apparent reorganization to a complexity which could be described as flexible" (1941, p 231) His results contradicted the view of Spearman (1927), who assumed that the intellectual abilities measured by the *g* factor would increase during adulthood and remain stable afterwards until the onset of senility, as well as the notion of Garret (1946) that intelligence is at first a general ability which dissolves during life into a group of loosely connected special abilities

In another factor analysis Goldfarb (1941) studied the relationship between the Wechsler Intelligence Test and various reaction time measures Since he used young and middle-aged subjects only, his study is not of special interest for our purpose In contrast to this, Birren (1952) analyzed with Thurstone's Centroid Method the Wechsler results of 90 persons between the ages of 60 and 74 years Four orthogonal factors could be identified verbal comprehension (V), perceptual closure (C_1), memory (M), and induction (I) It was also possible to regard V and C_1 as a higher order factor which in comparison to immediate understanding and learning during the test situation, represents the stored knowledge and experiences of older persons and is particularly important for their achievements Next, Cohen (1957) factor analyzed the data of the new standardization of the Wechsler Intelligence Test (1955) as well as of its extension to the age groups over 60 years conducted by Doppelt (1955) Cohen subdivided the sample into four age groups—18–19, 25–34, 45–54, and 60–75 years and over—and used an oblique rotation to simple structure for the centroid factors He obtained the following results (1) three correlated primary factors (verbal comprehension, perceptual organization, and memory) could be detected for all age groups, while two unidentified specific factors did not appear in the age group 60–75 years and over, (2) a *g* factor revealed high loadings in every subtest and accounted for about half of the subtest variance, (3) a factorial invariance over the age range studied could be noted, and (4) in the age group 60–75 years the memory factor attracted large parts of the variance on account of the *g* factor, and thus there was revealed a dependency of the achievements on retention and memory in old age

Finally, Ruth Riegel (1959) factor analyzed the data of the German standardization of the Wechsler Intelligence Test (1956) conducted by Anne Hardesty and Lauber and its extension to the age groups over 55 years (K F Riegel, 1958*a*) She subdivided the sample into four age groups —20–34, 35–49 50–64, 65–75 years and over—and applied Thurstone's Centroid as well as Hotelling's Principle Component methods Basing her interpretations primarily on the latter, she criticized Balinsky for not taking sufficient account of the general factor Her findings were in close agreement with Birren's results, which could be specified, since it was shown that the achievements during old age are more determined by general and redundant experiences and less so by specific knowledge which predominantly accounts for the verbal achievements during younger years

The studies just mentioned were restricted to a structural analysis of intellectual (cognitive) components As pointed out before, it has been suggested repeatedly that we abandon the traditional distinction among cognition, conative, and affection and attempt an analysis of their combined effects Necessarily, such an analysis has to be concerned with psychic phenomena in which all these components intimately merge, and, consequently, the study of concept, attitude, and interest structures has been suggested for such an investigation While little can be said at present about the concept structure and concept for-

mation during old age and while we shall discuss some investigations on attitudes and attitude development in another section of this chapter some attention will be given here to studies on interests and interest changes during later years which as soon as they are concerned with the dependency of the interests on other variables are of special value In most studies such information is given Thus Kuhlen and Johnson (1952) studying the interest expectancies for later years found that the expected changes correlated highly with changes of biological needs that is about at age 30 the concern shifts from marriage to profession and to family status and differentiations between persons increase Investigations on a larger basis have been conducted by Terman and Miles (1936) and by Strong (1931)

Terman applied his Attitude Interest Analysis Test to about 3000 persons between the ages of 20 and 90 years This test not only consists of interest questions but also asks for different associations opinions value judgments and general information and was primarily designed to yield an index of the masculinity/femininity of the subjects Terman found a decrease in Mf scores for the males while the scores of the females remained relatively constant over the whole age span The decrease in Mf scores was determined by lower preference for sports and dangerous activities and greater preference for quiet work Strong (1943) who applied his Vocational Interest Inventory to four groups of 200 persons each averaging 25 35 45 and 55 years of age and to 500 persons 15 years old developed scales on the masculinity/femininity of the subjects His test consists of 400 items about the preference for jobs hobbies activities personality traits etc In general Strong supported Terman's findings and noted that the decrease in Mf scores for male subjects begins shortly after the age of 15 years Aside from these findings Strong (1934) presented information on the kind of interest changes which occur with age He regards the twenty fifth year as a crossing point in the development of a person, before and after which interests are relatively consistent but almost reversed in their directions After the age of 25 years the interests decrease in activities jobs and hobbies which require quick adjustment produce excitement and involve danger while an increased preference could be noted for activities like gardening discussions real estate business etc Moreover Strong studied interest changes in various professional groups by retesting his subjects after periods of about 20 years In general a great interest stability was revealed by test retest correlations of about 75 The stability however was again dependent on the kind of activity originally chosen Thus the interests of persons from professions which involve danger and sudden or unpredictable happenings changed comparatively more than those found among members of other professional groups

While Terman did not restrict his inquiry to isolated interest patterns Kelly (1955) analyzed their precise relationship to various other components of the adult personality In addition to Strong s Interest Inventory he applied the Allport Vernon Scale of Values Bernreuter's Personality Inventory Remmer s Generalized Attitude Scales and self rating scales on personality variables to approximately 300 persons between the ages of 20 and 30 years Repeating the inquiries after 20 years on a large proportion of this group Kelly was able to show that approximately 50 per cent of the variables measured showed significant changes with advancing age The interests and value preferences proved to be most stable while the attitudes and self rating scales showed the most marked differences between the two test administrations In particular, there was an increase in religious interests attitudes, and value preferences and a drop in self esteem Furthermore Kelly studied the co variation of the various measures between married partners Moderate or low positive correlations could be observed for the first testing period, but, in spite of all

changes noted for single variables, no increase in the congruencies between the partners took place with advancing age. Generally, Kelly's observations suggest further studies over large portions of the life span in order to discover which personality variables are stable and which are not and what influences may cause changes. Cattell (1957) made an interpretation of Kelly's results in his own factor analytical terminology and prescribed some additional data (see Table 2) without specifying, however, his findings in detail.

TABLE 2*

NORMAL TRENDS IN Q DATA PERSONALITY FACTORS WITH AGE

Factor	Rate of Change per Year in S.T. (Score × 100)		Verbal Summary
	Age 16–34 Years	Age 34–60 Years	
A Cyclothymia	0	0	No change
B Intelligence	0	−5	Slight late fall
C Ego strength	+3	0	Slight early rise
E Dominance	0	0	No change
F Surgency	−3	−2.5	Continuous fall
G Superego	0	0	No change
H Parmia	+5	+3.5	Continuous rise
I Premsia	+8	+3	Marked early rise
L Protension	−9	−3	Marked early fall
M Autia	0	0	No change
N Shrewdness	0	0	No change
O Guilt proneness	−9	−5	Marked fall
Q1 Radicalism	0	−1	Very slight late fall
Q2 Self sufficiency	0	0	No change
Q3 Will control	+4	+4	Continuous rise
Q4 Id pressure (ergic tension)	−8	−4	Marked fall

* After Cattell (1957).

VI. LEARNING

Learning theories may be contrasted with theoretical systems which stress the structural aspects of personality as well as with those which grew out of the research on intelligence and projective testing and which are characterized "by the decision to remain within what one might call 'field' or 'neutral observation' methodology" (Lambert, 1954, pp. 77–78). Whereas in these theories such problems as "seeing," "wanting," and "purposing" have been frequently viewed as given properties and as explanations rather than as phenomena to be explained, learning theorists attempted to analyze the changes of psychological components and to specify the principles of these changes. Moreover, learning theories displayed an increasing tendency toward generality, according to which the same concepts and explanations are appropriate to describe psychological processes, for example, in lower animals as well as in men. This tendency, co-ordinated with systematization and idealization, is of course characteristic for other theories too. Thus Freud regards the personality systems of the id, ego, and superego as of such generality that they are equally representative for at least all human beings. However, he and other theorists have inferred a great number of specifications in order to account for differences among sex, age, ethnic, pathological groups, etc. So far little attention has been given in learning theories to deduce propositions which account for these differences in terms of basic con-

cepts of the theory Being restricted to the study of situations where changes in re sponse are likely to occur the extensions of their approach to the field —to the cultural social and personal interactions—may lead however to such deductions Finally learning theories are among the few approaches which take the time varia ble into account Although at first restricted to the analysis of short term changes the extension of this approach to long lasting developmental processes will undoubtedly have great significance for research and theorizing about the aging personality Learning theories and the literature on learning and aging have already been re viewed by Kay (chap xviii) and by Jerome (chap xix) Both of these chapters were concerned with the processes of acquisition and retention and the conditions affecting these processes whereas the present chapter is concerned with learning in the broader context of personality and personality development

Hull s Theory

Among the psychologists who extended learning theories in order to account for individual differences Hull (1943 1951 1952) has especially to be mentioned Hull s theory is based according to Dollard and Miller (1950) on the following con cepts *dri e cue response* and *reinforce ment* Dollard and Miller pointed out that for the human being the innate equipment of response patterns to inner or outer stimuli is rather limited It consists of a few reflex mechanisms an inborn hierarchy of preferred responses to some general stimuli such as noise heat etc and some primary drives A *primary drive* such as thirst hunger sex etc is an internal stimulus which activates the individual without directing his behavior Under outer influences however the individual soon de velops response patterns which may become evoked by secondary rather than by pri mary drives A *secondary drive* such as fear appetite desire etc may become attached to new or originally neutral cues and is frequently associated with verbal habits Speech and words such as Watch out and "I love you may mediate the particular response pattern A secondary drive such as fear is a cue as well as a response since it provokes response pat terns which reduce the stimulation and since it is linked to some stimuli which have been previously learned as fearful

Since human beings are provided with an inborn equipment which allows only to a l mited extent for successful actions the subsequent learning processes become of major importance Learning takes place when *responses* to some *cue* stimuli are produced which lead to a reduction of the inner excitation aroused by the drives The cue stimuli determine the kind and the time of the responses but during the early stages of development the responses are also highly dependent on the innate order of response preference As development proceeds this *innate response hierarchy* becomes substituted by a *resultant response hierarchy*

Similarly as the primary drives become superimposed by secondary drives as the initial response hierarchy becomes super imposed by the resulting response h er archy and as the cue stimuli gain increas ing importance in comparison with the drive stimuli the primary reinforcements are replaced by the secondary reinforce ments Generally *reinforcement* plays a central role in Hull s theory since by the reward given certain responses become pre ferred in comparison with others A re sponse is considered as reinforced when it leads to drive reduction (e g eating be comes reinforced since it leads to a reduc tion of the hunger drive) However even under these simple circumstances the re duction of a drive is dependent on a great number of prerequisite correlations like the access and preparation of food These con ditions need to be fulfilled first and be come strengthened by *secondary reinforce ments* Reinforcement in general leads to the strengthening of cue response bonds to the development of *habits* which determine

more or less autonomously the subject's actions Secondary reinforcement means the transference of the reinforcing capacity to previously neutral stimuli like the manipulation of food

Because one cue situation will never exactly resemble any other, the subject has to generalize his previously acquired experiences in order that progressive learning can take place The *generalization* will be greater the more alike the two cue situations are Since aside from the response directly rewarded some neighboring responses given immediately prior or shortly afterward for instance may become simultaneously reinforced there exists also a spread of the effect of reinforcement called the *gradient of reinforcement* As a result of the generalization and the gradient of reinforcement the individual will often give a response sooner than learned in the original response sequence and thus eliminate unnecessary steps in the approach of a goal The possibility of generalizing is again highly dependent on the development of verbal habits since as Hall and Lindzey (1958) pointed out the labeling of a situation as threatening or a person as an enemy may facilitate significantly the transference of corresponding reactions to similar situations or persons

> Not only may words serve to facilitate or inhibit generalization they may also serve the important function of arousing drives Further words may be used to reward or reinforce And most important of all they serve as time binding mechanisms permitting the individual to instigate or reinforce present behavior in terms of consequences which are located in the future but susceptible to verbal representation in the present It is clearly the verbal intervention in the drive cue response reinforcement sequence which makes human behavior so complex and difficult to understand and at the same time accounts for much of the difference between man and lower species [1958 p 439]

Extensions of Hull s Theory

Hull devoted much of his later efforts (1945) to the adjustment of his behavioral laws to the differences in species and individuals pointing out that all equations to be derived are generally identical except for the empirical constants Hull thought that the verification of this hypothesis would open an entire new approach to the scientific study of aptitudes and would mark a genuine junction between the various branches of pure and applied behavioral science However in spite of these elaborations Hull has not made clear (Hilgard 1948) what seems to be the basic problem of the relationship between learning and relatively persistent individual differences namely whether or not learning will modify these constants of the equations It has not been demonstrated explicitly whether these differences have to be explained primarily by the variability in the innate equipment (reflex mechanisms response hierarchy and primary drives) or by deviations in the environmental influence and thus may be due to the amount and kind of cues presented the reinforcement given and the subsequent response pattern and habits developed Furthermore great difficulties would arise if one used Hull s abstract formulations for a description of the individual s behavior or his behavior deviations in everyday settings What seems rather important for such a purpose is to refer to the characteristic *qualities* of his environment that is to the kind of stimulation and the form of reward given at the present moment as well as during the past life of the individual

With regard to the necessity to specify old and introduce new concepts in order to describe individual deviations Hull s theory does not differ essentially however, from most other personality theories Freud for instance is forced to take many special environmental events of the life history into account if he wants to explain exactly why a certain individual or a group of individuals differ from others in their behavior In contrast to the clinical elaboration of Freud and his followers learning theory has not become extended in this direction until recently Dollard *et al*

(1939) Miller and Dollard (1941), Mowrer (1950) and Sears (1951) have probably made the most serious efforts to integrate clinical especially psychoanalytic knowledge into learning theory However as helpful as this attempt would be in increasing the precision of psychoanalytical formulations it is doubtful if this extension would be equally valuable for learning theory and it may be possible that there are other ways more congruent with the original intentions and constructions Although the changes over time play an important role in any learning process it is surprising to note for instance how little attention has been given thus far to the development of cue response bonds over long time intervals and to individual differences in part or total amount of stimuli previously presented Probably the theory which comes closest to such an approach and which thus seems most relevant to gerontology has been outlined by Guthrie

Guthrie s Theory

Guthrie (1935 1944) considers the simultaneous occurrence (contiguity) of stimulus and response as a sufficient condition for learning namely the development of stimulus response bonds while for Hull this process has to be accompanied by reinforcement Including the concept of reinforcement Hull s theory is burdened as Meehl (1950) has pointed out with the problem of a circular definition reinforcement is the necessary condition that learning can take place and the existence of reinforcement is inferred from the strengthening of stimulus response bonds Eliminating reinforcement and simultaneously the unlearned ability to appreciate rewards, Guthrie seems to put less weight on the innate equipment of the organism than Hull does especially since the latter has recently de emphasized the notion of habit strength in favor of excitory potential (Lambert 1954) For Guthrie the structural basis of behavior lies in receptors, a connecting nervous system, and muscles and glands however, the movements and acts of the person are primarily of interest for psychological analysis An act consists of movements, it is a class of movements defined by an end result which, in a learning situation, become associated with stimulus patterns

In order to understand observed acts, Guthrie takes the whole associative history of an individual into account and subsequently gives way to the notion that a person can never be exposed to an exact reproduction of any situation The development of movement or response patterns is the result of a unique, adventitious combination of stimuli and a movement sequence which, if it does not cause trouble and thus new learning, becomes fixated Yet every man has his individual stereotyped style of acting, and therefore it is meaningless to speak about general personality traits like rebellion against authority, or neatness or promptitude ' Every neat person has his own mode of being neat—the comparatively stereotyped movements by which neat results are accomplished in that situation (1944, p 61) The possibility of predicting a person's behavior is dependent on the fact that, by the continuous repetition of movements, the person develops habits which are relatively resistant to change and which make up what Guthrie calls ' personality " The development of these habits is dependent on the systematization of institutions and culture to which the individual is exposed Generalization and transference of learned associative bonds as well as discrimination between cues are not conceived as prerequisite abilities in Guthrie s theory The individual has to acquire a whole repertoire of movement sets fitted to various situations Also the concepts of drive and motivation do not represent primary principles of learning They determine merely the presence and produce differences in the strength of movements, as one can observe between hungry and well fed cats However, the learning process itself is dependent on the

association between the movements only the cat learns what it does

In de emphasizing the importance of re inforcement and drive as well as of gener alization and discrimination Guthrie s the ory seems on the one hand to be simpler but on the other even more abstract and less precise than Hull s system Frequent ly Guthrie has based his statements on general descriptions of behavior like his description of cats in puzzle boxes and on everyday observations and thus his theory lacks not only the rigorous formalization but also the sound empirical background which makes Hull s system outstanding However in spite of these shortcomings the simplicity and the flexibility to account for thus far unrelated variables like indi vidual differences seem to give his theory a good starting position for the competi tion with other systems His almost rare consideration of learning as a cumulative process over long time periods marks a gen uine junction between personality theory and developmental psychology

A Related Study on Aging

During recent years different attempts have been made to combine the divergen cies reflected in Guthrie s and Hull s theo ries into dualistic systems as well as to translate Guthrie s theory into a more pre cise and formal language However up to the present time hardly any attempt has been made to interpret research findings on aging in terms of these theories Since the related studies and theoretical considera tions on learning of older persons in gen eral have been discussed in Jerome s and Kay s chapters of this *Handbook* it may be sufficient here to refer to one illustrative study only in which the present writer (1959) investigated verbal achievements of older persons by administering five multi ple choice tests (synonym antonym selec tion classification and analogy test) to 74 persons above the age of 65 years and to 56 persons with an average age of 18 6 years The theoretical framework has some relationship to Guthrie s theory on associa tive learning as well as to recent investiga tions with word association tests by Jenkins and Russell and on intra individual asso ciation structures by Schaefer Peterson and Jenkins (1957) Based on their sugges tions the author derived an association model which contains stimulus and re sponse words of the various tests applied (see Fig 4)

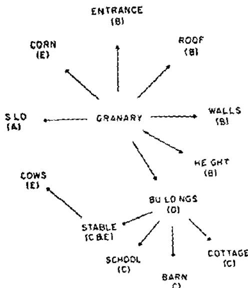


FIG 4 — Associative links of the test word GRANARY to possible response words of four verbal tests (A) response word of the Synonym Test (B) possible response words of the Selection Test (C) possible response words of the Classification Test (D) supraordinate for the response words of the Classification Test and (E) test words and response word of the Analogy Test

It was reasoned that associations be tween words which are linguistically and logically (*sprachlogisch*) related to each other (e g synonyms co ordinates supra ordinates subordinates etc) should be come strengthened during life by the con tinuous accumulation of information and by the adaptation of the person to general linguistic patterns Therefore tasks in which use of these associations can be made should reveal some *advantage* for people who had (because of their age) more experiences of

this kind These associations play an especially important role for the solutions of the Synonym Test because there exists only a very limited number of possible associations namely synonyms to a given word in any language Excluding all except the Selection Test from our discussion here a subordinate to a supraordinate or in the more general case an essential characteristic or part of a thing has to be recognized for the solution of the task that is the response word has to denote something which always belongs to the object referred to by the test word In this task a great number of possible response words—associations—exist to a given test word (some of which are shown in Fig 4) however only one answer has been chosen as correct for a test item Accordingly even if all possible connections become strengthened during life thus giving some advantage to older persons the great number of these associations requires some specific discriminations—the recognition of the relationship particularly demanded by the test item Thus the strengthening of all possible associations which gives older persons some advantage becomes less significant in this test than in the Synonym Test

The theoretical framework has also been stated in terms of information theory referring especially to the concept of redundancy and accordingly it was reasoned that older persons were relatively favored the more the tasks require the use of redundant information The hypothesis derived in the study may be stated as follows The achievements of older subjects on verbal tests decrease in the order synonym antonym selection classification and analogy tests This and related hypotheses have been verified and thus a first test of the model has been obtained Since, however only indirect measures of the association process have been taken so far further research has been directed toward the association process itself by applying word association tests to older persons Although the use of these tests may be relevant to personality interpretations for clinical psychologists, they were applied only to secure information on the cognitive structure in old age as well as on some long term changes of verbal habits Nevertheless the connection of the study with Guthrie s theory may be suggestive for future research and interpretations of the aging personality

VII The Field

Lewin s field psychology belongs to the few theories in which some tentative interpretations of the aged or at least the mature personality have been made Surprisingly enough this interest of Lewin s is maintained in spite of his ahistorical view of the personality, which seems to be in contradiction to most of the traditional developmental analyses Many students in gerontology emphasized the close dependency of the aging process on social conditions and gave voice to the notion that a person with limited environmental possibilities cannot be adequately compared with those who have lived under different circumstances Since Lewin in particular takes these factors into account his theory seems to be very appropriate for an analysis of the aging personality Among different applications studies on attitudinal development during later years are closely related to Lewin s work

Lewin s Theory

Giving strong emphasis to the close interactions between inner personal and environmental factors Lewin (1954) regards the behavior of a person at a given moment as a function of the coexisting facts with in his *life space* (*Lsp*) his *psychological field* The study of his behavior (B) has to begin with this totality of a situation proceeding to differentiate it into its component parts and generally has to analyze two variables the person (P) and his environment (E)

$$B = f(Lsp) = f(P \quad E)$$

The environment of a person is only a restricted part of the outer world and in

cludes only those variables which have some psychological effect on the individual There exist also physical components within the psychological environment, as there are social components in the so called *foreign hull*, the latter being not relevant, however, to the subject's present behavior The *boundaries* between the life space and the surrounding foreign hull are permeable in both directions Thus physical events, for instance, an accident, may produce significant changes in the life-space and thus on the person, the person as well may change the foreign hull Also the boundary between person and environment has the same bidirectional quality With regard to the person further distinctions as between the *inner personal region* and the *perceptual motor region* have been suggested by Lewin For a differentiated person the inner personal regions as well as the psychological environment are subdivided into a number of smaller sections These sections may be more or less loosely connected with each other according to their nearness/remotedness, the firmness/weakness of their boundaries, the fluidity/rigidity of the medium out of which they exist

The personality structure as viewed by Lewin is characterized by its momentary duration Lewin has little interest in fixed or inherited personality traits, instincts, or

historical background, Lewin regards any age scale as highly misleading for a description of the individual's development and for an understanding of psychological growth Instead one should refer to the degree of differentiation, organization, and integration of the subject's behavior Using Lewin's terminology, the life space of an older person would be characterized by a great number of clearly differentiated regions within his psychological environment but especially within his personal region "As one grows older the variety of his activities, emotions, needs, information, and social relationships increases, at least up to a certain age Thereafter the versatility of his behavior may show a contraction" (Hall and Lindzey, 1958, p 235)

The developmental stages are also characterized by the boundary properties of the regions, especially since the number of boundaries necessarily increases with the number of differentiations Generally, the boundaries within the life space of a child are less firm than those of an adult, and a child may therefore more easily substitute one need, as represented by one region, for another Furthermore, the integration between different regions increases with advancing age The needs of a child may spread over from one region to another, whereas during adult years these regions become more isolated, on the one hand, and evolve into a hierarchical order, on the other—an interpretation which explains the ability of adult persons to organize and execute complicated actions Lewin points out that the increase in differentiation with advancing age includes also a differentiation in time perception, or, as Deutsch remarks "Plans extend further into the future, there is an increased tolerance of delay, and activities of increasingly longer duration are organized as one unit As the individual matures, his picture of the possibilities which exist in the future play an increasingly important role in determining his morale" (1954, p 192)

Lewin's theory takes full account of dynamic psychological processes which become represented by the continuous restructuring of the personality and have been denoted by the concepts of need, psychical energy, tension, force, and valence *Psychical energy* is released when a person returns from a state of tension, which arose between different regions, to a state of equilibrium Thus *tension* has the important property of calling for equalization among different regions, for example, in solving a task, tension may arise which leads to thinking in order to reduce the tension until equilibrium is reached and the task is completed Equilibration means that tension is equalized between all regions un-

less the boundaries are so firm that any further exchange is hindered in which case a more or less permanent extensive reservoir of cumulated energy may be developed by the person. The arousal of tensions is caused by *needs*. Lewin uses this concept in an extremely pluralistic way and rejects strongly the intentions of older scholars to systematize the needs and to reduce them to a few categories. There are as many needs as there are concrete wishes. In order to explain motor actions in detail Lewin finally introduces two other concepts: valence and forces or vectors. *Valence* is the value of a region in the psychological environment of a person and depends on his needs. A *force* or *vector* is also co-ordinated with a need and is directed to the psychological environment. Thus generally need becomes a rather central concept in Lewin's theory. A need increases tensions, releases energy, imparts value, and creates forces.

From Lewin's formulations some further inferences about the aging personality can be drawn and the inner state of the aged person can be characterized as one in which no strong and effective tensions arise because either the barriers between the different regions have become too rigid or the general energy level has been significantly lowered. Furthermore it may be inferred that older persons may become more easily irritated by a loss of their equilibrium and thus may not anticipate as well as younger persons the right moment for tension reduction in order to perform actions. This latter interpretation is suggestive from Lewin's theory as well as from empirical findings in aging. However, before quoting a few studies in which constructs of this theory have been applied, we shall draw attention to some aspects of the theory which have attracted critics previously.

Evaluation and Extension of Lewin's Theory

Lewin, stressing the importance of a systematic approach to psychology, explains the behavior of a person out of the contemporaneity of his total situation, the life space, and does not take the historical development of an individual into account. Although this approach does not seem to be appropriate for studying phenomena of aging, there undoubtedly remains the possibility of comparing different discrete life-spaces along the age continuum. However, this attempt would only lead to some kind of cross-sectional comparison of life spaces and does not exactly account for the functional dependency of various events on each other which occur at different moments in the development of the subjects. Strictly speaking, it would be justifiable to specify *differences* only between various situations but not functional changes during development. Lewin has made at least two revisional remarks on the problem of contemporaneity.

First, he points out that the phrase "situation at a given time" does not refer to an instant without time dimension but has to be conceived in terms of the duration of meaningful psychological units. Lewin writes that "the first prerequisite of a successful observation in any science is a definite understanding about *what size of unit* one is going to observe at a given occasion" (1951, p. 157). The second revision seems to be more embracing and expresses the idea which Lewin owes to Adams of treating "the factors determining development formally in the same way as the factors determining behavior" (Lewin, 1954, p. 919 n.). Thus development (DP) is also dependent on the state of a person (P) and his environment (E), and we could write in analogy to the above formula $DP = f(P, E)$. However, the great generality of this formulation may lead to some doubts of the usefulness of his statements for practical research. What is needed are some specifications as to the variables constituting the environment and acting within the persons, especially with regard to those which allow for measurement and thus for empirical testing. This lack of concreteness in his formulation has led some psychologists, among whom Barker and Wright (1949) need to

be mentioned to give more specificity to his model

Lewin s theory is outstanding insofar as he attempted to translate his concepts and their interrelations into the language of mathematics However as Deutsch pointed out Lewin s topological and hodological concepts are not much more than diagrammatic representations of his brilliant theoretical and experimental insights (1954 p 199) This restriction may be due not so much to a lack of an isomorphism between his theoretical concepts and mathematical formulations as to Lewin s refutation of a step by step demonstration between both these constructs and the measurements taken Lewin states The mathematicians have to realize that to apply a system of mathematical concepts in an emp rical field one does not necessarily have to prove directly the adequacy of the basic mathematical axioms of this system one by one (1940 p 22) Instead he refers to a general pragmatic evaluation in continuing There can be no other meaning and no

tion (1940 p 22) The lack of clarifying precisely the relations between measurement and concepts has led Spence and others to the question of how far Lewin s experimental work has at all anything to do with his theoretical formulations In using an abstract terminology Lewin described his ideas only in a general way but even mathematical formulations did not help to translate these ideas into the language of empirical science

Stimulating experiments within the framework of his theory Lewin was inclined to proceed from more general to more differentiated states and emphasized the study of pure cases —cases for which

be due only to the effect of so called constituting factors Giving some examples on how one should proceed in eliminating these error variables Lewin (1927) pointed out that finally the description of the life space of one of these pure cases represents what he has called a law whereas the opposing approach is led by the strategy to study simultaneously the various interactions between a great number of variables none of which can be conceived on a prior basis to be more influential on the total configuration than any other

Generally modern psychologists have been inclined toward the latter approach for which multivariate experimental designs and factor analysis are appropriate tools Studying pure cases on the other hand not only burdens the experimenter with the task of deciding more or less on a priori grounds which var ables have constituting properties and which do not but also leads to laws less general than those obtained by using modern experimental techniques (Riegel 1958*b*) The study of pure cases may be an adequate approach to problems where the constituting and the accidental var ables are relatively easy to differentiate in psychology however this is hardly ever the case and generally it will be a goal of the experiment itself to detect which of the variables represent constituting factors and which do not Moreover it has to be recognized that there exists no clear dichotomy between constituting factors and errors and that the distinction between both is always a matter of degree and has to be related to the amount of variation which any single variable contributes to the total variance Lewin caught up by German philosophical traditions regarded this distinction rather as qualitative in nature and thought that the individual in his uniqueness should never be described by statistical methods applicable to cumulated data only However at present it is becoming apparent that statistical methods may well be used to study single individuals that is to study one person s behavior in a time sequence as Rogers Stephenson Burt and others have tried On the other hand since Lewin does not show clearly how one should proceed in studying pure cases and

how constituting factors may be separated from error variables, it is not surprising, as Sibylle Escalona (1954) has pointed out, that, independent of Lewin's great general influence on psychology, only a few attempts have been made to translate precisely his topological and vector constructs for the study of developmental phenomena

Studies of Rigidity in Aged Persons

Kounin s (1941) study of rigidity, age, and feeble mindedness is probably one of the most perfect translations of topological and vector constructs into personality research and shows some of the many possibilities still inherent in Lewin's theory Kounin proposed two general theoretical models that rigidity is a positive monotonous function (1) of chronological age and (2) of the degree of feeble mindedness, the latter being in reality a corollary of the first From these models Kounin deduced five hypotheses

> Other things being equal the older and/or more feeble minded an individual 1 The less effect a change of state in one region will have upon the state of neighboring regions 2 The less likely he is to be in an overlapping situation 3 The more difficulty he will have in the performance of a task which requires him to be influenced by more than one region 4 The more likely is he to structure a new field which is perceptually ambiguous into a relatively large number of separate independent regions (achieve a less integrated structure) 5 The less easily he can perform a task which requires that he restructures a given field [1941 pp 270–71]

To test these hypotheses, Kounin operationally defined the following five tasks and explained in detail their relationship to the hypothesis and the concepts used (1) satiation in figure drawing, (2) transfer of habit on a bar pressing apparatus, (3) card sorting in simple and overlapping situations, and (4) and (5) form color sorting under changing instructions Three special groups of 21 subjects each were used, comparable in their mean mental age on the Binet Test (80, 82, and 82 months) and differing in chronological age in the following way old feeble minded group (41 7), young feeble minded group (14 5), and young normal group (6 8) The results showed definite differences between each of the three groups, and thus it was concluded that "any performance which requires a certain degree of communication between neighboring regions (the degree of communication being inversely proportional to the degree of rigidity) is to such an extent made difficult for the older and/or feeble minded individual" (1941, p 271) Kounin regarded the phenomenological nature of the performance as unimportant The task may be predominantly of a cognitive, motor, or "volitional" type, for as long as it "is facilitated by the lack of communication between neighboring regions, such task will be more efficiently and accurately performed by an older and/or more feeble minded subject" (1941, p 271)

We could of course relate these interpretations to various findings, especially on the differential age effect on motor and cognitive functioning discussed in other chapters of this *Handbook* However, restricting our discussion to rigidity as a complex personality variable, only a few attempts have been made so far to study its development through the later years Heglin (1956) administered Luchin's Water Jar Test and an alphabetic maze test developed by Cowen, Weiner, and Hess to three groups of 100 subjects each with median ages of 16 05 31 75, and 62 02 years The first test consists of a series of simple arithmetic problems in which, given three water jars, each holding a different amount, the subject is required to get a prescribed amount of water As in the Water Jar Test, the subjects solving the set problems of the second series tend to build up a habit of following a characteristic, indirect path from start to finish Then, on the critical problems, a shorter path is also made available, while, on the extinction problems, the new path only can possibly be used The number of

set solutions among the four critical prob lems represents a measure of the subject's rigidity

In their results the older group revealed the highest degree of rigidity, while the middle group showed less and the younger group least The older subjects resisted subsequent training most strongly, while the middle group showed least resistance and finally excelled the younger persons in their avoidance of the more complicated

Test to 74 persons above the age of 65 years, he observed, however, that subjects repeatedly failed to find the correct solu tions to the tasks and therefore were not susceptible to learning the set either)

Mangan and Clark (1958) administered eleven tests (seven cognitive perceptual and motor rigidity tests and four reasoning tests) to 50 persons between the ages of 40 and 55 years By factor analysis they ex tracted three factors one for which the cognitive rigidity and reasoning tests at tained the highest loadings and which was identified as a general "attitude to test taking' factor and two other factors on perceptual and on motor rigidity Since however, in this analysis age was not in cluded as a variable, the authors could only suggest that "the administration of a simi lar battery of tests to a younger sample

to show a more modest loading' (1958 p 425)

A similar study on a broader basis was conducted by Schaie (1958) who tested 500 adults ranging in age from 20 to 70 years who were subdivided into 5 year groups of equal size He applied Thurstone's SRA Primary Mental Ability Test and his own Test of Behavioral Rigidity Schaie presented detailed results which may be summarized in the following way A sig nificant decrease with advancing age in all measures of mental abilities and a significant increase in all measures of behavioral rigidity were noted Considerable differences between the various scales existed as to the degree of change, location of the peak and amount of variability The correlations between the measures of rigidity and the mental abilities were significant throughout the adult age span, with a tendency to decrease toward the upper end of the age continuum

Recently, it has been emphasized by Rokeach *et al* (1955) that the distinction between structural rigidity and behavioral rigidity may be viewed as the genotypical and the phenotypical aspect of rigidity and confronted with the construct of dogmatism in the following way

> Dogmatism refers to the total cognitive *or ganizations* of ideas and beliefs into relatively closed ideological systems rigidity when genotypically conceived refers solely to the degree of isolation between regions or to a property of functional boundary which prevents com munication between neighboring regions , when phenotypically conceived rigidity is de fined in terms of the way a person or animal attacks solves or learns *specific* tasks and problems Dogmatism has a further reference to the authoritarian and intolerant manner in which ideas and beliefs are communicated to others [1955 p 87]

Riegel in an unpublished study, has made use of this distinction and has applied scales of dogmatism and rigidity to 5 year groups of 76 persons each ranging over the age span from 55 to 75 years and older and to 120 persons with an average age of 17 9 years in northern Germany The question naires were refined by cluster analysis and were similar to those developed by Rokeach *et al* (1955) and, respectively, by Gough and Sanford (1952) The rough data obtained are shown in Figure 5

Finally, Botwinick *et al* (1957) studied the effect of 'set" in relation to age in measuring the reaction time to auditory stimuli "Set" refers here to a short term expectancy and was varied by differences in preparatory intervals between the stimulus and a visual warning signal The great-

est difference in reaction time between the younger (20–36 years) and the older group (61 83 years) was contiguous with the shortest preparatory interval The hypotheses that were suggested therefore were either that the elderly group required more time for preparation or that they required more time to overcome the effect of an overestimated interval of time (1957 p 304) The concepts used a detailed discussion and two related but unpublished studies by Botwinick *et al* and by Weiss are reported in chapter xxi of this *Handbook*

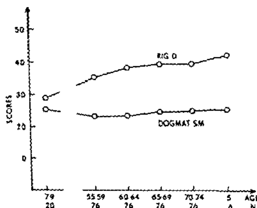


FIG 5 —Mean dogmatism and rig d ty scores of six age groups (maximum sco e 56 m nimum score=0)

VIII THE SOCIAL ROLE

Many personality changes which occur during later periods of life have been attributed to the influence of environmental factors (e g to changes in social demands or popular beliefs about the abilities of older persons) Role theory more than any other systematization takes account of these dependencies and thus seems appropriate for an analysis of the aging personality Moreover different research investigations not only have been stimulated by role theory but in turn have furthered its extension into such difficult domains as that of adjustment during old age For this reason role theory may be regarded as a good example for the co ordination between theory and research and thus for future inquiries into the psychology of aging In contrast with many other theories role theory has been developed not by the efforts of a single person but by a number of scientists among whom Park and Burgess (1924) Mead (1934), Cameron (1950), Newcomb (1950), and Sargent (1950) should be mentioned In recent times Sarbin (1954) has given probably the most elaborated outline of role theory

Role Theory

Early writers on role theory referred to the personality as an internalization of roles and regarded a role as a pattern of attitudes and actions To Sarbin this heterogeneous conceptualization made the deduction of testable variables as well as the linkage between empirical research and theorizing difficult Placing much weight on the concept of self and thus revealing his inclination toward Rogers' theory he conceives the personality as determined by the interactions between self and role A role is a more or less automatic and unconsciously organized action of a subject in an interacted situation with another person elicited by perceptive and cognitive clues On the basis of the reaction of the other person and new conceptualizations certain expectations are developed by the subject Having located or named the position of the other he performs certain acts which have been learned as the reciprocal position Roles are intentionally or incidentally learned (e g by instruction or as an adoption of the prevailing pattern [Cameron 1950] in play situations) and cannot necessarily be judged by others as something apart from the individual but may be perfectly integrated into his behavior In addition Sarbin differentiates among seven levels of organismic involvement which are closely related to the degree of self involvement in the role enactment The first level as represented for instance, by a customer in a supermarket, is characterized by minimal participation and by minimal interactions between self and role On the higher

levels the degree of organismic involvement increases Finally, a particular role has a certain value or status in the eyes of the community Status may be defined as the general evaluation level of a role In turn the individual values himself at the level of roles which he occupies, he may, however modify this status according to other personal qualities Roles change under cultural and historical conditions these changes however, are difficult to analyze, as are the development of roles and role expectancies within individuals Up to the present time almost no study on this topic has been performed under controlled experimental conditions

Sarbin's emphasis on the concept of the self characterizes his deviation from sociological views According to Sarbin the self is what the person 'is,' the role is what a person 'does' When interested in the self we regard the person as an organization of *qualities* When we study roles we regard the person as an organization of *acts* Parenthetically, direct observation reveals only action systems resulting from the interplay of self and role' (1954 p 244) The self as an intervening variable originates out of the interactions of two series of events The first the maturational series can be assumed to be fairly independent from cultural influences, the second the personal social series, is determined by individual and group variations Furthermore Sarbin following Werner's (1926) earlier distinctions, differentiates among five developmental levels of the self Thus the self is seen as an organization first unverbalized and later verbalized by gestural linguistic, and manual performances Werner especially refers to the dimensions of differentiation, time binding and tension binding, and, accordingly, the adult person may be characterized as differentiated and able to tolerate time and tensions within relatively wide limits, while the child cannot wait and admit delay between stimulus and response During the later years the use of language becomes increasingly important, and the differentiation proceeds in roles rather than in discrete acts and leads to the development of the social self

The interpretation of adjustment by role psychology is of special interest, since a great number of related studies on aging has been conducted recently Generally, it has been accepted by role psychologists that the person s adjustment is dependent on the number of roles especially standard roles he knows how to enact Thus a maladjusted older person may be characterized as one who did not acquire adequate roles for old age during the previous years The arising conflicts are of two kinds (1) self role conflict and (2) role role conflict Especially the first type of conflict may adequately describe the difficulties of older persons and express the incongruencies between the perceived structure of the self and the role an older person is expected to enact For instance a subject may regard himself as a quite able adult person but may be forced to enact a role of an old man or vice versa The conflicts of the first kind lead to behavior which has been conceptualized by role psychologists in much the same way as by psychoanalysts, namely as ego defense mechanisms In contrast, the role role conflict which may arise between one s role as a soldier and as a Christian refers to behavior deviations in general The handling of these conflicts is characterized by the attempt either to establish a hierarchical order of the roles or to segregate them

A framework similar to the one proposed in role theory has been outlined recently by Henry (1956) for the investigation of the aging process and Havighurst (1956) suggested some rating scales for measuring the corresponding variables In contrast to Sarbin Henry refers closely to psychoanalytical theory and ego psychology, especially to the work of Hartmann and Kris as well as of Erikson (1950) He proposes two major axes for the study of the adult personality *affective complexity* and *role perception* The first refers to the complexity of inner affective experiences the inner reality, the second, to the perceptions of

available roles in the individual's social life space For possible investigations Henry differentiated this distinction more clearly by devising further subcategories Under the category *inner reality* he grouped the variables body image sexuality and affect intensity under the category *conception of the external world* personalization generalization nature of external environment and role perception and under the category *interaction of self and external world*, nature of inner motivation action initiation and complexity scope and alternative resolution Henry pointed out that he derived these categories by empirical investigations of normal adult persons however he gives no detailed information about his approach

Studies of the Roles of Older Persons

Since experiences resulting from enactments of roles during later periods of life may have a significant effect on the organization of behavior the analysis of roles is important for the psychology of aging General social cultural changes may also reveal such influences Merton (1940) demonstrated for instance the influence that a bureaucratic institution has on the individual Out of daily practice in enacting roles which are clearly defined and regularized a development of the self arises which may be characterized as rigid Similarly, Waller (1932) discussed the interaction of role and self analyzing the question of what "teaching does to the teacher" Various examples of the influence of social variables such as status retirement institutionalization etc on the aging personality are discussed by Kuhlen (chap xxiv) in this *Handbook*

A number of studies have been conducted on the perception of roles of older persons as well as of the attitudes *toward* older persons and their activities Tuckman and Lorge reported detailed results on this topic and found that persons who use chronological age as a criterion of aging, who specify a low chronological age for its beginning, or whose own age is closer to the age they conceive as the beginning of old age subscribe more to stereotypes about old people than those who have different views (1953*e*) According to their interpretations chronological age seems to be a poor index of aging, since it fails to take into account the wide-ranging differences among persons The years most frequently mentioned as the beginning of old age are those between 60 and 65 (1953*f*) Supplementary to this are the findings of Sarbin (1954) that women related significantly more often than men the role perceived to the age of the person, while men emphasized the relationship between role and social situation Chandler (1950), Havighurst (1950), Kirchner *et al* (1952), Kirchner (1957), and Tuckman and Lorge (1952*a* 1953*a*) studied the attitudes toward older persons and their activities, the latter also studied the dependency of these attitudes on such factors as institutionalization (1952*b*, 1952*c*), training (1952*d*), changed directions (1953*c*, 1953*d*), and family environment (Tuckman, Lorge, and Spooner, 1953)

An interesting controversy has been brought up by Tuckman and Lorge (1953*b*) and by Tuckman, Lorge and Zeman (1954), who detected a relation between subjective health ratings and general stereotypes about the health of older persons Applying the Cornell Medical Index and a supplementary health questionnaire to older and younger persons, they found an improvement in health status with advancing age Taking general stereotypes about a low health status of older persons into account, these subjects seem to have overestimated their own health Therefore according to Tuckman and Lorge's view, these findings are in agreement with those of Busse *et al* (1954), who reported objective medical findings and found a continuous decrease in the health status of aging persons In a supplementary study Tuckman and Lorge (1958) showed that the acceptance of stereotypes about health is a

function of reported symptoms Besides these inquiries a number of anthropological reviews have been published on the role and treatment of older persons and the attitudes toward age in other societies Koty (1934), Simmons (1945*a*, 1945*b*, 1946, 1948, 1952), Chandler (1949), and Eva Lips (1953)

The studies discussed so far have given information on the perception and evaluation of the roles of the aged, as viewed by different groups of the total population and under different social conditions In the following studies the role enactments of the older persons themselves are the object of investigation Here the research initiated by the Social Science Research Council's Committee on Social Adjustment in Old Age needs to be mentioned An early report on the activities of this committee was given by Pollak (1948) Cavan *et al* (1949) made inquiries on the nature patterns, and problems of personal adjustment to aging, while Ruth Albrecht (1951*a*, 1951*b*) and Havighurst (1952, 1953), especially, devoted their research to the study of roles and status of older people In their preparatory work the authors defined eleven role areas (shown in Table 3) of older persons and characterized them by a number of interests and activities thus obtaining the items of a questionnaire which they administered to 100 persons over 65 years of age These subjects represented a cross sectional sample of a midwestern county seat of 7000 population In order to gain a general social evaluation of the various role activities, the same questionnaire was used, but modified in such a way that the subjects had to denote their general approval of the various activities in which older persons may be engaged Administering this questionnaire to almost a hundred persons of each decade above the age of 20, the authors were able to show, among other interesting results, that the social evaluation of the activities of older persons did

questionnaire, in order to determine for every older person the extent that he was engaged in specific, socially approved activities In summing up these scores for each person, an estimate of his personal adjustment could be obtained

As mentioned above, the adjustment of a person will be dependent on the number of roles he knows how to enact and on the social evaluation of these roles in public

TABLE 3*

DISTRIBUTION OF MEAN ROLE ACTIVITY RATINGS AND MEAN SOCIAL APPROVAL RATINGS BY ROLE AREAS
(Strata Sample of 100 Persons over 65 Years)

	Mean Role Activity Rating	Mean Social Approval Rating
Great grandparent	5 04	3 41
Grandparent	5 11	
Parent	7 12	3 37
Home	6 90	3 34
Kinship	4 73	3 03
Social club	2 07	1 90
Business club	1 10	
Church	3 15	2 41
Informal social group	3 72	2 26
Age group	4 48	3 23
Civic	3 23	3 28
Occupation	5 04	2 96
Leisure	4 95	3 49
Total	4 44	

* After Havighurst and Albrecht (1953)

opinion Havighurst and Ruth Albrecht were able to test empirically this proposition by administering simultaneously two other independent adjustment measures to the subjects—the scales "Your Attitudes and Activities" and the "Cavan Adjustment Rating Scale"—and found correlations of 60 and 76 between these scales and their social approval scores of the inquired activities of the older persons The study described yielded, of course, a great number of more specific findings which are related to differences in role activities according to age (correlation — 22), socio economic status (correlation 47), sex,

etc Information on the mean ratings of the various role activities is given in Table 3

Other attempts to apply concepts of role theory for studying adjustment of older persons have been made by Zena Blau (1956) and Phillips (1957) Both their interpretations are again closely congruent with Sarbin's view of role and self perception and both emphasize age identification as an especially crucial intervening variable for perceiving age changes Blau remarks that 'age identification rather than actual age constrains older people to recognize changes in themselves and to perceive that the attitudes of others toward them have changes" (1956 p 203) Among the objective changes, only retirement hastens the onset of old age, probably because it relates to social judgment rather than to natural events and removes the subject from significant social communications and from the identification with younger age groups Blau based her interpretations on an analysis of interviews from approximately 450 persons above the age of 60 years, and Phillips on an additional 500 subjects, in the New York area Phillips elaborated especially the relationship of age identification and role changes to adjustment which was found to be significant among all three variables Although he admits to have used relatively crude measures only, his study represents another example of how empirical research on aging may be co-ordinated with a theoretical framework, thus helping to increase the precision of the concepts used and the integration of various research results

IX Contemporary Approaches to Personality

In the preceding parts of this chapter some concepts have been specified which have become central in personality theory and which may be particularly important for a personality theory of aging We shall subsequently direct our attention to some contemporary approaches which have brought about methodological refinements as well as a greater recognition of the requirements for theory constructions discussed in the introduction of this chapter Although most of these attempts are not concerned yet with personality research in a narrow sense of the word, they nevertheless may stimulate the work in this area as well as in psychological gerontology.

Formalization

The early approaches of psychophysics as well as behaviorism are characterized by their use of the "classical" model of experimentation and by their application of unidimensional experimental designs. Wundt, as one of its earliest proponents in psychology, claimed that the experimenter should analyze and isolate the significant variables before beginning his experiment and that he should vary them in consecutive steps in order to study their effect on the dependent variable. The general goal of these experiments was to find laws of the relationship between stimulus and reaction of the following forms

$$R = f(S)$$

Opposing this approach the *verstehende* psychology claimed that any reaction or sensation is dependent on the uniqueness of the individual (I) Hofstätter (1949) has characterized this view by the formula $R = f(I)$ and pointed out that one could feel somewhat ashamed about the long lasting quarrel *verstehen* versus explaining, since the unifying view,

$$B = f(P, E),$$

had been proposed early by K Buhler as well as by Lewin Lewin regards the behavior (B) as dependent on personal (P) as well as on environmental factors (E) however, he has failed to specify the variables of this "relatively empty formula" (Lambert 1954) Graham (1950) made such an attempt, generalizing at the same time Lewin's two dimensional schema

$$R = f(a, b, c, d, \quad , n, \quad , t, \quad , x, y \ z)$$

Here a, b, c, and d are aspects of the

stimulus, *n* corresponds to the number of times the stimulus has been applied to the organism, *t* gives notion to the time variable, and *x*, *y*, and *z* are internal conditions to set, motivation, etc

Graham's formula and its representation in complex experimental designs are as characteristic for contemporary approaches to personality and personality theory as for psychophysics and behaviorism Personality may be viewed as a network of the many structural and dynamic psychological variables, their interactions, and their dependency on biological and sociological components Structural as well as dynamic variables—the conceptual and methodological problems related to the latter have been discussed in Section V of this chapter—are denoted by the letters *x*, *y*, and *z* in Graham s formula, they need, however, still more specification for personality research The inclusion of time and stimulus repetition, which refer to some short as well as long term time lapses, is of special significance for developmental psychology Many psychologists have based their theories from the beginning on experimentation and related experimental designs, and more recently attempts have been made to reformulate others Thus great parts of the psychoanalytical theory have been recast into the framework of learning theory by Dollard Miller, Mowrer, and Sears, theories which emphasize the uniqueness of the self or motivational forces have become closely linked with factor analytical or experimental techniques, structure, learning and field theories, being always dominated by great empirical and methodological concern, became increasingly formalized, as revealed in the work of Cattell and of Lewin but especially in Hull's theory Conceiving this formalization as the prevailing and desirable scientific trend, McGuigan (1953) discusses the possibilities of applying logical, mathematical, or probability systems to psychological theories to attain greater clarity and consistency of conceptualization

Estes (1950) and Estes and Burke (1953) attempted to clarify some of the conceptions of learning and discrimination and developed a statistical theory of elementary learning processes based on a likelihood measure for the responding behavior and on the variability of stimuli in a statistically defined environment Analyzing the relations between probability and rate of responding and making no assumptions on the properties of certain aftereffects of response such as drive reduction and changes in affective tone, Estes did not need to select any ' of the investigators' belief as to the nature of underlying processes (1950, p 107) Like Guthrie, he considered the temporal contiguity of stimuli and behavior as a sufficient condition for the formation of conditional relations A number of psychologists—Sheffield (1951) Wyckhoff (1954), Restle (1955)—have approached learning theory under similar views while especially Bush and Mosteller (1951) as well as Bakan (1953) developed mathematical models in terms of reinforcement concepts All of them did not take however individual or developmental differences into account

Bush and Whiting (1953), following Miller's (1948) formulations of displacement phenomena, described stimulus generalization in terms of mathematical set-theory and assumed that punishment of a response has the effect of removing the organism from the situation and thereby reducing its opportunity to respond Extending their model to social settings (i e, to situations where a great number of stimuli are present), they proceeded to take inter individual differences into account Attempts have been made also toward greater formalization of Tolman's cognitive theory Here Brunswik's (1955) plea for representative designs and probabilistic theory and Meehl's (1951) and MacCorquodale s (1953) suggestions on formalization of expectancy theory need to be mentioned Brunswik argues in favor of studying psychological phenomena in representative samples of their natural setting

and is opposed to the systematic attempts in experimental psychology, as well as in personality research and theorizing of selecting more or less on an a priori basis the decisive variables in their optional or in abnormal gradations

Communication

The attempts to formalize theories like those of Guthrie Hull and Tolman are similar to some work related to Lewin s field theory and his social psychological experimentation However as many as these attempts were restricted to the study of conditioning and learning the theorizing to be discussed here is related to interpersonal communication and hardly takes personality differences into account As mentioned earlier Lewin also made serious efforts to superimpose his theory by a system of concepts borrowed from topological and vector calculus He has been followed in this attempt by some of his students of whom Bavelas (1948) and Harary and Norman (1952) developed theoretical models of communication patterns in social groups Lewin regarded the group as a dynamic whole in which a change in the state of any subpart may change the state of any other Studying these structural and dynamic properties Festinger *et al* (1950) have analyzed the *cohesiveness* of the group which they define as the total field of forces which act on members to remain in the group and the *pressure to communicate* The second phenomenon has been attributed to three forces (1) communications arising from pressure toward uniformity (2) communications arising from forces to locomote in a social structure, and (3) communications arising from the existence of emotional states While the latter source of communication has seldom been investigated so far, its study is undoubtedly most relevant for personality research

Aside from the social psychologists' interest in communication processes, these phenomena have become increasingly important for the analysis of message channelization and transference Especially the concepts of *information* and *feedback* have been applied in various fields of research whereas formalizations led to the development of a new set of statistical methods Both concepts, equally relevant to environmental personal and organismic (e g homeostatic) interactions, may become extended to personality research and the study of the aging organism However since information theory and related research on aging have been already more thoroughly discussed in Kay s chapter of this *Handbook*, it may be sufficient to draw attention to Osgood s (1957) related propositions Osgood criticized the stimulus response interpretations as well as the sign significate theory of Tolman because the first said little or nothing about the integration of sensory as well as of response events while cognitive theories have failed to explain the actual performances which may constitute the response to the perception of some stimulus pattern. Moreover both theories did not add much to the understanding of symbolic processes which are according to Osgood, the core of an analysis of psychic processes, since they include the very complex organization both of perceptual and of motor skills

Avoiding the use of the traditional distinctions since perception as well as language processes contain cognitive, conative and affective components, Osgood differentiates like Welford (1958) and others between the *decoding* and the *encoding stage* of organization in a complete behavioral act While the decoding stage denotes the process by which physical energies of the environment are interpreted by the organism, in the encoding stage the intentions of an organism are expressed and turned again into environmental events Furthermore, Osgood differentiates among three levels of organization applying to both the decoding and the encoding stage (1) the *projective level*, which relates by neural mechanisms receptor as well as muscle events to the brain, (2) the *inte*

gration level, which organizes and sequences the events, and (3) the *representation* or *cognitive level,* which is at once the termination of decoding operations and the initiation of encoding operations Since the analysis of symbolic organization provides some of the most direct routes to complex psychic processes, Osgood's propositions may give new stimulation to the research on personality and the aging individual

Reduction

The concepts "reduction" and "reductionism" are easily misleading, since in any theoretical analysis one finally will attempt to reduce the manifold of observed events to a few basic factors However, reductionism in a narrower sense of the word denotes the attempt to relate psychological variables to a neurophysiological basis This view, suggested in early as well as in recent publications by Gestalt psychologists, was strongly rejected during the twenties and thirties and criticized again after its re-emphasis by Hebb (1949), Klein, Krech, and others Klein and Krech (1951) pointed out that personality research has developed in protest against the tendency in early experimental psychology to parcel out its subject matter according to some special interests in the laboratories However, the protesting "personologists" also failed to overcome this separatism, since they tried to derive laws of the subsystem "whole man" and did not integrate

[illegible]

i e in terms of the meaning it has for the subject" (1951, p 9) Psychological functions have no meaning apart from their being events of the physiology of the organism they are only translations of these A psychological theory will require a retranslation in which the entire behavior of the organism is merely viewed as some series of neurological, muscular, and glandular events

Reductionism has its inherent attraction of unifying separate scientific disciplines and possibly of improving the methodological basis of measurement Moreover, reductionism yields independent variables capable of explaining psychic events, while any intercorrelation of the latter reveals circular explanations only However, in his critical discussion Jessor (1958) pointed out that the behavior of a person, defined by its organism environment interactions, is something over and above its physiology, since ' the terms and the laws of the latter refer to intraorganismic or intradermal processes, or, at most, relations between an organism or its parts and the space defined by physics" (1958, p 173) Jessor denied the possibility of reducing psychological variables completely to neurophysiological events a notion which is undoubtedly shared by many writers On the other hand an increasing amount of successful experimentation has given much stimulation to this approach, and even if the results obtained seem to be still remote for a description of the personality, those variables which best withstand any thorough analysis (e g emotion and motivation) may become best understood by a study of their neurophysiological basis This approach may also be highly significant for an analysis of psychological changes during old age As an example Birren and Botwinick (1955*a*) did a study in order to test the hypothesis that the increase in reaction time during old age is dependent on a decrease in neurological functioning These authors presented auditory stimuli to groups of old and young subjects, varying the length of the nerve track by requiring that the response be given alternately by the finger, jaw, or foot They found a significant general increase in reaction time, but they could not verify the proposed hypothesis and were led to the assumption that the changes in performance during old age were caused by a decrease in the effectiveness of the central rather than the

peripheral parts of the nervous system While this result has undoubtedly only remote bearings on personality theory, the experiment may be nevertheless suggestive for future research because of the simplicity of its arrangement and the ingenuity with which the problem was analyzed

Explication

Recently, different approaches to personality have been suggested which originated out of the study of relatively limited psychic phenomena but have been increasingly extended and used to account for complex types of behavior (Blake and Ramsey, 1951) Among these and like some investigators discussed in Section IV above, Helson (1955) in his theory of the adaptation level regards *adjustment* and *organization* as the two fundamental concepts for a science of behavior Whereas earlier attempts were restricted by isolating the various activities into conventional theoretical units such as sensation, reflex, ideation, or memory, they are but partial expressions of the adjustment and organization of the organism In order to make finer differentiations, Helson has drawn attention to the influence of background and of anchoring stimuli on perceptual judgments of hue, lightness, saturation, loudness, pitch, taste, and tactile qualities and on judgments about attitude statements In most of his studies the anchor as well as the stimuli were of a physical quality, however, in the latter investigation the individual's judgments were related to the group opinion and thus were viewed in a social context Furthermore, factors like past experience and willingness to co operate have been used as background stimuli, and the method has been applied to the study of psychotic behavior and the effects of electroconvulsive shock treatments

Helson has summarized his approach as follows

> Personality no less than perception can be regarded as the pooled effect of stimulus, background, and residual factors manifesting itself in characteristic patterns of behavior The normal individual is centered in the temporal present and in his immediate spatial environment While cognizant of past and future, he weights stimuli in accordance with their nearness, frequency, intensity, and, even more importantly, in accordance with their significance or value for him as a person We thus envisage personality in much the same way as we have treated perception—namely, as a system in which the energies released by internal and external forces are balanced, giving rise to ordered responses Just as the physiology of the organism is directed toward preservation of normal temperature, normal pH content of the blood, and the preservation of the numerous other constants characterizing a state of health responding to stresses to minimize their effects, so at the behavioral level we postulate a psychological homeostasis to parallel the well known physiological homeostasis by which our organic activities are governed. The critical problem for personality theory is to understand how residuals develop how they interact with present stimulation to modify behavior, and how they can be modified or counteracted by appropriate control or manipulation of environmental factors to make possible adjustment of the organism to changing internal and external conditions [1955, 98–99].

While, up to the present, similar approaches to the aging personality have not been reported, there exists a number of studies on psychomotor functioning which, taken together, are comparable to Helson's work in that, by the continuous and more or less systematic search for new, related factors, the somewhat narrow impact of the variables has become increasingly broadened and inferences about other fields have been drawn Based on Miles's (1931) early distinction between movement and reaction speed, later investigators studied the dependency of these variables on problem difficulty, complexity, and age Thus Birren and Botwinick (1955*b*) measured the speed of discrimination between tachistoscopically presented lines of different length Since the longer reaction time of the older subject was dependent on the difficulty of the task (i e , the older subjects

were relatively quicker in their discriminations between widely differing lines), the authors inferred that the general decrease in achievement could not be explained merely by the perceptual difficulties of older subjects. Further differentiations have been made as to choice reactions, the initiation, execution, and ending of a movement sequence, the resting period after the performance, the length and variability of successful continuation, and the performance with and without time stress. The various results have led Welford (1958) to the application of the concept "short term memory" in his interpretation of performance changes during old age which has been discussed in his chapter of this *Handbook*. From the same findings and his results on the writing speed of older persons (1951), Birren (1956) has reasoned that during aging a learned movement sequence may break into its separate components and that older persons may thus become unable to inhibit required reactions until the right moment for the performance has come. Like the disturbances of the short term memory these changes may hinder the integration of single performance acts into a broader context and make the performance closely dependent on the information immediately preceding the actions.

The studies quoted are characterized by their methodological precision and reveal in their combination a network of functional

TABLE 4

SUMMARIZING CHARACTERIZATION OF PERSONALITY THEORIES

Investigator	Content					Form and Method					Concern about Aging		
	Biological Basis	Uniqueness of Self	Interpersonal Structure	Learning Processes	Social Basis	Comprehensiveness	Interindividual Approach	Intraindividual Approach	Empirical Emphasis	Historical Orientation	Original Account of Aging	Application to Aging Phenomena	Type of Possible or Actual Applications
Kretschmer	x*	o*	x	o	o		x	o		o	o	o	Psychosomatic interactions
Sheldon	x	o	x	o	o	o	x	o	x	o	o		Longevity
Freud	x		x			x		x	o	x	o	x	Psychotherapy; Evaluation of the person as a whole
Goldstein	x	x	o									o	Psycho-physiological interactions
Murray	x	x			x					x		o	Psychotherapy
Adler	x	x			x			x	o	x			Evaluation of the individual
Allport		x						x					
Rogers		x	o		x	o	o	x	x				
Cattell			x			x	x		x			x	Structural changes
Hull		o	o	x		x	x	o	x		o	o	Accumulative processes (learning)
Guthrie	o		o	x		x	x		x	x			
Lewin	o				x	x		x		o		x	Environmental imbeddedness (attitudes)
Sarbin			o		x				x			x	Social behavior (adjustment)

*x = high emphasis o = low emphasis blank = neither high nor low emphasis, no relevance, or unclear position.

ly related variables which may become integrated into a theoretical system similar to those characterized before, and similar to, Helson's theory Although again the results and interpretations sketched do not reach clearly into the domain of personality research, they may be nevertheless suggestive for future inquiries in that they are decidedly opposed to the many far-reaching generalizations and to the neglect of methodological precision which previously has often characterized the approaches on which personality theories have been based

X Conclusion

The purpose of this chapter was threefold to give reviews of some personality theories, to discuss their extension to phenomena of aging, and to refer briefly to studies on aging which have some relations to these theories Also the problems brought up in this chapter seemed to be threefold denoted by the concepts 'aging," "theory," and 'personality ' While the methodological difficulties in the study of developmental processes were discussed only briefly (this has been done in Birren's chapter of the *Handbook*), some attention has been given to the necessary requisites a theory such as one of personality and aging should fulfil Personality, it furthermore was pointed out, may best be represented by a formal system and viewed as a network of the many structural and dynamic psychological variables, their interactions, and their dependency on inner biological and outer sociological components The inclusion of time and stimulus repetition is of special significance for an analysis of the aging personality The representation of the personality system by an experimental design does not lead, however, to any concrete definition of personality. Here the theories differ with regard to what they conceive as the major axis or dimension of personality While these variations do not need to be reviewed in detail, some general characteristics of the theories have been summarized in Table 4 following similar categorizing by Ansbacher and Ansbacher (1956) and by Lindzey and Hall (1958)

Up to the present, no theory exists which takes full account of the aging personality For possible extensions the following conclusions may be made: (1) All verifiable knowledge about personality has to depend on responses of the subjects For better control, these responses should be provoked by artificially arranged stimulation, and the variables studied should be closely linked by empirical definitions to measurement procedures (2) The great diversity of variables which thus may be studied requires theoretical systematization The discussion may have shown which concepts exists and should not be left out of such an integration (3) Since personality theories differ much as to their emphasis of specific aspects of personality as well as to their methods of approach, it can hardly be expected that any one of them will definitely excel the others (4) For this reason it may be of greater advantage at the present time, and at least for basic research in a new domain such as the psychology of aging, to study only subsystems—perceptual, learning, or social processes and their developmental characteristics—rather than the total personality all at once, hoping that one day all these different aspects may become integrated into a single system (5) It was emphasized that greater formalization may be a first step toward this goal

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XXIV

Aging and Life-Adjustment

RAYMOND G. KUHLEN

Many of the preceding chapters in this volume deal with the matter of adjustment, sometimes directly, as in the chapter on psychopathology, but more often indirectly, as in the chapters on changing physical and mental capacities to adjust, the chapters dealing with changing opportunities, expectations, or limitations upon adjustment set by the culture, or the chapters on work and play which describe modes of achieving various gratifications But there remains the matter of the general adjustment of the individual, how adjustment varies with age or with factors related to age, and how, too, changing adjustment may in turn be a causal condition determining a variety of personality and other changes with age Accordingly, the present chapter will review the literature in which "adjustment" is viewed as the dependent variable and age as the independent varia
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causally responsible, at least in part, for many changes that have been shown to bear a relationship to age The general point of view expressed in this chapter has been set forth elsewhere (Kuhlen, 1956), the reader is also referred to S L Pressey and R G Kuhlen, *Psychological Development through the Life Span* (1957), especially the chapters dealing with dynamic and social aspects of development

I Definition and Measurement

The term "adjustment" usually refers either to a process or to a state of the organism As a process, the term makes reference to the ways in which an organism achieves satisfaction of its needs, thereby reducing tensions, particularly under those circumstances when it is thwarted, that is, when its customary ways of meeting needs are blocked or prove inadequate "Process," as such, presumably does not change with age, presumably, the *principles* of adjustment are the same throughout life But capacities change, the types of problems change, the repertoire of habits (both adaptive and maladaptive) change, and the mechanisms utilized for adjustive purposes likely vary in incidence with age

When the term "adjustment" is used to describe the state of the organism, reference is made to the degree to which the organism is in a state of equilibrium not only within itself but also in its interaction with the environment Since some states may be viewed as representing more or less optimal adjustment, a person may be (and often is) described as being *well* adjusted or *poorly* adjusted The criticism that they are dealing with value judgments is thus often leveled at those who are concerned with psychological adjustment, and accordingly it becomes important to state as explicitly as possible the criteria by which quality of adjustment is judged Such criteria define in a major way the con-

tent of this chapter For readers who are cautious or even suspicious of the making of value judgments regarding adjustment, the facts presented in this chapter will serve to describe the changing state of af fairs in certain aspects of behavior as age increases and will be of interest in their own right. For others, such facts will serve as a basis for inferences regarding the general quality of adjustment and will inevita bly raise questions regarding the "desira bility" of observed trends and what can be done about them

Adjustment may be viewed in at least two frames of reference, social and person al. In its most general sense, social adjust ment means the adjustment of the individ ual as externally evaluated against formal or informal criteria set by others A person is judged as well or poorly adjusted against cultural norms of what is good and desira ble Often the term is used in a narrow sense to refer to adjustment *to others*—whether the individual has friends, inter acts with others, or conforms to the recognized rules for social interaction whether established by local custom or national legislation And *other people*—employers, courts, peers—make the judgment as to whether adjustment is good or bad

In contrast, the term *personal* adjustment refers in the main to the *subjective* aspect of adjustment Regardless of how
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may be quite unconscious in the sense that the individual may in fact be unaware of his goals and may be unable to identify, observe, and/or report upon them, nor may he "see" the relevance of his behavior to his goals or to his biological or social needs In any event, the major criterion of good adjustment involves the adequate and integrated satisfaction of the individual s complex of needs, viewed personally In such terms, it is conceivable and, in fact, not infrequently true that a person who is viewed *socially* as a failure or as malad justed is *personally* quite adequately adjusted or that a person who is judged by others as extremely competent and successful may be an abject failure in his own eyes

The major lines of evidence, or the major symptoms of personal adjustment, tend to be specified by three groups of questions First, is the individual subjectively happy and contented? Does he have positive self regarding attitudes? Second, is he relatively free of handicapping anxiety? Third, does he have a degree of frustration tolerance and flexibility that enables him to meet and deal constructively with various stress sit uations without evidencing undue anxiety? In studies of aging it is the third question that may be the critical one The crucial question often is not how happy and free of anxiety is the person *now* but how well he can *maintain* this state of affairs as he meets the inevitable crises of aging

Although it is frequently useful to make a distinction between social and personal adjustment along lines suggested above, it is often difficult to do so Social values and norms tend to become "interiorized" and personal during the course of personality development, and social evaluation of adjustment, as reflected, for example, in bi ases toward older age groups, may constitute important personal threats affecting personal adjustment On the other hand, culturally (even though professionally) de rived criteria and value judgments are in volved in assessing the "adequacy" of personal adjustment

Problems of definition and conceptulization have tended to hinder research in the area of adjustment and aging In the main, studies of adjustment and aging have been descriptive, with chronological age being the independent variable Fortunately, oc

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this direction in 1948 (Pollak) But much needs yet to be done in the clarification of definitions and concepts before they can be translated operationally into instruments

of measurement Aside from problems of definition (which incidentally, seem to be only superficially solved in areas such as intelligence) the measurement of personal adjustment as a function of aging is complicated by the fact that adequate research requires measures applicable to individuals over a broad age span Unfortunately most existing measures of adjustment (as is true also of intelligence tests) have been developed validated and normed on groups in late adolescence and early adulthood or at best over a relatively narrow range of years in later maturity or old age Such tests may well have *clinical* value even when appropriate only for individuals of a very narrow age range but their *research* value in a developmental psychology of the adult years is likely to be limited because such research must of necessity involve comparisons among subjects from widely different age groups

A first problem in the measurement of adjustment in research on aging relates to the matter of *stimulus equivalence* Ideally, the stimulus situation presented by the test —whether it be a paper and pencil test a projective test or a laboratory situation —should have approximately the same psychological meaning for the 30 year old, the 50 year old the 70 year old, and (indeed) the 90 year old Jones and Conrad (1933) concluded that paper and pencil tests could not be adequately administered to samples beyond 60 Yet many tests' of adjustment are of this type A TAT type stimulus picture may contain an 'old couple' of approximately 60 years of age A 30 year old sees them as parent figures, the 60 or 70 year-old as contemporaries, the 90 year old as the younger' generation Stimulus materials related to specific types of developmental tasks are likely, for example to represent stress type materials only for individuals in the age range characterized by those tasks and are not so likely to produce anxiety type reactions in other age groups In these illustrations the same stimulus objectively is patently not the same stimulus psychologically in studies contrasting greatly different age groups not that this is ever (strictly speaking) the case, but in developmental studies covering a broad age range the stimulus may not even be of the same class Perhaps the answer to this problem lies in attempts to build 'age free' or 'age common' tests or tests finely balanced in stimulus materials representative of the different decades

A second major problem relates to the matter of *response equivalence* Ideally, responses should have approximately the same psychological meaning or diagnostic significance for groups over the age range studied This is not likely to be the case when tests are built and normed on one age group, and the same items and scoring procedures are then utilized for a very different age group Willoughby (1938) pointed this out some years ago Avoidance of crowds, for example may be keyed in the maladjusted direction for an adolescent who is in the socially most active period of life, but for an old person avoidance of crowds is the norm Does the same response imply maladjustment for the old person in view of the extensive reorientation of interests that have occurred? Separate validation of tests against external criteria for various age groups would seem desirable Mason (1954) and Caldwell (1954) have more recently called attention to this same need

Although some of the facts assembled in this chapter are derived from the administration of tests defective along both of the above lines, many of the studies reviewed do not employ such measures Frequently, the facts collected are those that reveal the age incidence of various types of symptoms of adjustment or maladjustment rather than yield a score that specifies a point on a *scale* of adjustment It is of more than passing interest that some of the more significant findings regarding changing adjustment are mentioned by investigators incidental to the description of sampling (non return of questionnaire, refusal to co operate, omission of items) or procedure and dismissed without explana

tion as if of significance only as they qualify the main results of the study In total the available evidence though in many respects faulty provides important insights into the subjective view of aging

II Changing Motivation and the Pattern of Life Adjustment

A previous chapter has presented evidence regarding changes in biological drives during the course of aging In another place (Pressey and Kuhlen 1957) the writer has suggested that physiological pressures and needs which dominate the life of the infant and later give way to social motives may reassert themselves in later years when dysfunction may pose serious frustration Greater concern about digestive and elimination functions in old age is a case in point Important as physiological drives are they are probably less significant in modern society than social or derived motives for the reason that with the exception of sex most biological drives are conveniently met What are some of the derived needs that seem especially significant in understanding aging? What are some of the basic sources of satisfaction and of frustration? How can changes in goal orientation be accounted for? And what about the view that the life course represents a working out of adjustment to basic needs? From considera

Positive Orientations Expansion and Basic Satisfactions

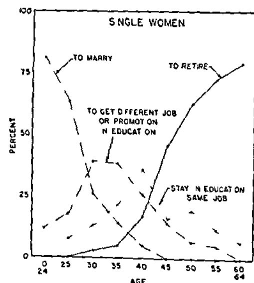
the human life course from the vantage point of the basic motivations involved from the point of view both of broad over all trends and of sequences of goals She has suggested that there is discernible in human lives a broad and pervasive need for continuous expansion a basic orientation toward the future (Buhler 1951) Other writers refer to a need for achievement a need for self actualization a need to occupy what is to the individual a *significant* role The postulation of a general need of this sort (i e expansion) seems useful in explaining and relating in a meaningful fashion a variety of changes in goals and interests as people move through life

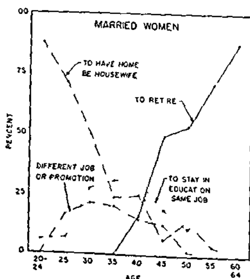
Marriage children and work seem to represent basic avenues of expansion for both sexes though there are of course significant sex differences in the importance of these avenues Anticipation in these directions is clearly apparent in even the verbalized goals of adolescents and young adults For single women up to the age of perhaps 30 the hope is for marriage for married women family roles prove demanding and rewarding until children have left home perhaps until 45 or 50 At roughly these ages new avenues of expansion must be sought if a sense of significance and accomplishment is to be maintained Single women at around 30–35 begin to become more career minded and around 50 married women are most active in organizations At this time and later a sense of continued expansion may be achieved by identification with one s offspring who are in an expansion phase while parents lives are growing stagnant In old age there appears to be an increasing belief in immortality which might possibly reflect the need for continued on goingness in extreme old age when other more earthly avenues are no longer open Such shifts in goals interests and values with age become related in a meaningful way if they are assumed to be manifestations of a general striving for expansion for on goingness for the achievement and maintenance of a significant role But the types of manifestations that characterize a particular life will depend upon the avenues that are open to and the values of the individuals concerned

It is difficult to find data illustrating these trends but the facts contained in

Figure 1 are relevant The data there presented represent responses of a group of public schoolteachers when asked what they would most like to be doing 10 years hence Most notable in these charts are (*a*) sex differences in long term goals (*b*) differences between single and married individuals in their orientations and (*c*) evidences of a sequence of goals as life moves on The shift around the age of 30 in the case of single women from orientation toward marriage to orientation toward occupational advance illustrates a shift in goals as one avenue of basic satisfaction is blocked A sense of frustration of achievement needs at around 40 in present work may be the reason for the increase in wish to get into a different type of work (i e other than education) on the part of the married men This study is only suggestive, but it does have the merit of focusing upon long term goals Only recently (Edwards, 1953, McClelland, 1953, Atkinson 1958) have systematic efforts been made to measure the strength of derived motives and these measures have as yet rarely been applied to adults of different ages

Another line of evidence as to changing motivation is to be found in the sources of satisfaction at different ages as reflected in studies of interests, activities, and values Kuhlen (Pressey and Kuhlen, 1957) has reported results of an interview study of sources of satisfaction Three sources predominated love, marriage, and family, occupation, and social relationships Happy experiences for married women stemmed





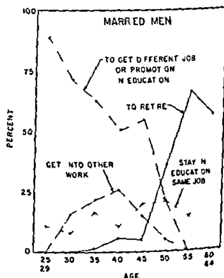


FIG 1 —Changes in goals with increasing adult age as reflected in the responses of public schoolteachers to the question "What would you most like to be doing 10 years from now?" (From Kuhlen and Johnson 1952)

mainly from marriage and family, for single women, from occupation and social relations, for married men, from occupation, marriage, and family The relatively restricted lives in terms of potential sources of gratification led by single women was reflected in the fact that only 2 5 per cent of the reasons they gave for happy episodes in their lives were classified in the miscellaneous category, whereas about 20 per cent of the reasons of married individuals both men and women, were classified in ties (Strong, 1943) From young adulthood onward social interests and participation decline, people tending to prefer a few close friends to many acquaintances and becoming more asocial and sedentary in their activities Membership in organizations and positions of responsibility within them, however, appear to increase until middle age and then to decline (Mangus and Cottam 1941, Mayo, 1950, Mayo and Marsh, 1951 Havighurst and Albrecht, 1953, Pressey and Kuhlen 1957)

TABLE 1*

DEGREE OF COMPANIONSHIP IN OLD AGE BY AGE PERIODS

Degree of Companionship†	Percentage Distribution by Age Periods							
	60 64	65–69	0 74	75 79	80 84	85 89	90–94	95 and Over
Males								
High	47	37	35	36	50	37	33	25
Moderate	43	52	51	49	39	53	68	50
Low	10	11	14	15	11	10		25
Total no. of cases	68	87	110	107	56	19	6	4
Females								
High	47	33	28	30	18	10	8	25
Moderate	45	45	50	49	46	45	53	25
Low	8	21	22	21	36	45	39	50
f	[illegible]	o	176	119	69	31	13	4

degree of companionship [illegible]

this category Among married men and women, marriage and birth of children were cited as major sources of satisfactions in young adulthood, in middle age, family and home life, and in older years, success

[illegible]

fications are found

Social relations involving individuals and groups constitute a major source of satisfaction at all ages, though interest in the broad range of social activities appears to be strongest in the late teens or early twen-

In [illegible] and associates through death, [illegible] tinued decline in companionship, but especially for women who are more likely to survive their husbands (Cavan *et al*, 1949) In fact, as Table 1 shows, the sex differences in trends beyond age 60 are striking The frequency of extreme social isolation in old age, even in situations such as a well run old people's home and a hospital ward where many others are *physically* present, is surprising (Burgess, 1954, Tallent and Lucas, 1956) These losses in old age are especially serious because of the

probable importance to good adjustment of being able to achieve a sense of significance, of worth and of belongingness through relating to other individuals and groups

The suggestion that religion offers special opportunities for satisfaction of basic needs in advanced years is based on a variety of studies showing an increase in religious interest and participation over a broad range of adult years Kelly (1955) reported an increasing favorable attitude toward the church on the part of the same individuals who were tested in their twenties and later in their forties and he cites a similar finding in an unpublished study by as likely causes of the low point of church attendance in the thirties In the years beyond 60 (which are undifferentiated in Table 2), church attendance, according to Cavan *et al* (1949), is maintained without significant drop until 90, but there was a steady increase in more sedentary types of religious observance, such as reading the Bible and listening to religious radio programs Most notable in this study is the finding that every one of 28 individuals beyond age 90 expressed certainty of an after life[1] Certainly, religious participation meets a wide range of human needs—social, aesthetic, security—but it is this last

TABLE 2*

RELIGIOUS PRACTICE OF CATHOLICS IN A SOUTHERN CITY

Age	No of Cases		Per Cent Making Easter Duties		Per Cent Attending Mass Every Sunday		Per Cent Receiving Monthly Communion	
	Male	Female	Male	Female	Male	Female	Male	Female
10–19	835	833	91	93	91	95	63	79
20–29	930	1064	84	86	73	78	41	41
30–39	924	1063	57	69	62	75	24	38
40–49	745	717	67	83	68	83	30	48
50–59	365	372	72	82	71	82	30	47
60 and over	216	299	75	95	83	96	17	32

* Source After Fichter 1952

Irving Bender Both studies being longitudinal in design may reflect possible cultural change in this direction rather than age changes (cf Nelson 1954) These studies sampled verbal attitudes some facts regarding church attendance and religious observance for a substantial Catholic population (Fichter 1952) are shown in Table 2 The thirties in this study appeared to be the low point in religious participation, with a steady increase thereafter into old age This last finding is especially significant in view of the fact that almost all other types of out of home participation are steadily dropping and are becoming less appealing as age increases (Strong, 1931, 1943, Briggs, 1938) Conflicting pressures and needs were cited by Fichter

finding that suggests the relation of religious concerns to the need for a sense of continued on goingness, even beyond death

ferent ages How are these changes with age goal in orientation, in motivation to be explained? One explanation lies in the assumption that needs are arranged in a hierarchy of prepotency and that lower level (more basic) needs must be relatively adequately satisfied before the higher level needs come into play (Maslow, 1943) In general, biological needs have priority over derived needs And certain derived needs take precedence over other derived needs It is not necessary to subscribe to the par

ticular needs Maslow places in the hierarchy or to assume that the same hierarchy characterizes all individuals to find in his formulation a very useful explanation of certain need changes during the course of life For example, most Americans start their postschool years with little economic reserve, with the result that the need to achieve economic security is likely rather basic, taking precedence over many other needs *Once this need has been satisfied*, it may no longer serve as a motivating force, and other needs may become important The change from an emphasis upon personal desires in young adulthood to a sense of duty in middle age noted by Frenkel Brunswik (1951) and the importance of the need for autonomy in adolescence and again in old age may be at least partially explained by the assumption that the more prepotent needs must be satisfied before those higher in the hierarchy become operative If, as in the illustration of autonomy needs, a previously satisfied need later becomes frustrated, it may assume importance again

If satisfaction of one need paves the way for the ascendance of others so also may the chronic frustration of a need result in its becoming relatively inoperative, thus giving rise to or permitting the emergence of new goals or orientations In Lewin's phrasing (1946) a person who is chronically frustrated with respect to a particular goal will "leave the field the goal no longer remaining within his life-[illegible]

family or community activities as sources of satisfaction The finding cited earlier regarding shift from orientation toward marriage to orientation toward career at around 30 to 35 years of age on the part of single women will serve as a second example But the desire to marry may again become very strong if there appears to be some likelihood that this may ensue This parallels, but conversely, the pattern suggested above in which needs may become inoperative once satisfied only to reappear if frustration should arise

There is also the possibility that sheer satiation with a situation may cause a decline in motivation in a particular direction Lewin (1946) calls attention to the likelihood that too much experience or too great familiarity with a situation will result in a certain satiation and a resulting change in motivation and Murray (1938) parallels his formulation of personal "needs" with the construct of "press" which refers to the potentiality of the environment to *arouse* and to satisfy needs The strong tendency on the part of adults to settle into set patterns of living—same neighborhood, same job same spouse—raises questions as to whether the decline with age in certain drives may be due to *stimulus* failure rather than to drive failure It has been noted, for example that sex activity of monkeys caged together declines as time passes, but, when caged with a new mate, sex activity rises to the earlier high level and then again declines with the passage of time To what degree the decline in sex activity noted by Kinsey *et al* (1948, 1953) and by Terman (1938) may be dependent upon a similar circumstance has, of course, not been determined Jersild and Tasch (1949) have observed that curiosity drives seem to be stultified by school programs during childhood and adolescence Such drives are likely, for most people, further reduced by sameness of life and lack of environmental demand It is not unreasonable to expect that this drive might be rekindled if an individual were somehow thrust into an appropriately stimulating or demanding environment

As a person experiences changes in roles as he grows older, he is likely to encounter new cultural expectations as to desirable behavior, purposes, and goals By definition derived needs are responsive to—indeed, to a large degree develop from—cultural expectations which are translated into systems of rewards and punishments Typically, cultures are characterized by age roles defined in terms of particular sets of

limitations privileges and expectations regarding behavior of people in that age group These expectations tend to become 'interiorized and a part of one's personal need system Shifts in valuing of various activities occur when a person marries, becomes a parent becomes 'middle aged' or old Adolescents may reject religion and violate many border line moral codes only to espouse conventional religion and morals and become in middle age the transmitter of convention to their offspring Some roles may be so demanding that they simply crowd other potentially satisfying activities out of the picture In human motivation the pressures of time and money that beset the busy mother and the breadwinner are likely every bit as important as are sundry biological pressures though greatly neglected in the formulations of academic psychologists

A number of reasons may thus be advanced for changes in motivation with age However in many instances the problem seems not that of explaining changes but rather that of explaining how certain needs may not only persist but become more intense with the passage of time Thus Reissman (1953) noted that even at age 56 high achievers were still more willing than low achievers to put up with certain inconveniences (e g moving to a new city) or restrictions (e g not discussing one's own political views) for the sake of a new opportunity that spelled advancement Success in career seemed to lead to a need for greater success rather than (as suggested above) paving the way for new motivations by making success no longer important It may be hypothesized that whether or not this happens will depend in part upon basic personality characteristics such as rigidity or flexibility and on the richness of the over all need structure of the individual and on the availability of alternative goals A man without wife and children has limited opportunity to turn to family interests once career success is achieved, nor, unless wealthy, can he become a philanthropist Or the drive (as for achievement) may be neurotic in origin, with the subject never really achieving *personal* satisfaction and security, though to an outsider he may appear to have been eminently successful Whatever the reason, constant reinforcement of one set of habits and the absence of reinforcement of opposing or alternative patterns may result in motives that have already become autonomous becoming even more so Allport s conception (1937) thus has relevance to the matter of aging One can in fact assemble a variety of cogent arguments for persistence of rather than change in motivational patterns Selective perception and learning, selective forgetting limitations of time and energy, threat of the new—all have the effect of causing the individual to live in a constantly restricted social matrix as age increases In an important sense it might be anticipated that as he gets older a person will become more like himself

In general, though goals may change, the obviously expansive phase of life is determined not only by strong desire for achievement and "expansion" but by the increasing competence in environmental manipulation which results from the growth of mental and physical capacities the development of culturally appropriate goals the accumulation of experience, and the chronological achievement of opportunity (granted in a sense, by society) to function with relative independence and in significant roles To show something of the pattern of expansion (and subsequent restriction) in the human life-cycle, certain features of the life of Elizabeth Textor Goethe, as presented by Frenkel Brunswik (1936), is charted in Figure 2 In this individual life are shown the increasing dimensions of life during adolescence and young adulthood, the culmination period of the thirties and forties, followed by loss of important dimensions in later years Figure 3 presents an array of curves which show the fundamental pattern of expansion and restriction that characterizes the life span Here are plotted data showing expansion restriction in such diverse instances

as family unit size, income, general social participation in community activities as well as in organizations, and extensiveness of the "psychological habitat" These curves simply document statements made earlier and serve to show something of the various spheres in which these trends are observable But the curve illustrating

situations in a community where life goes on Chart D in Figure 3 shows the results of actually checking on the physical places, in a small midwestern town, where people of different ages were to be found There was, as can be noted, a steady expansion of the 'life-space" with age, into adulthood, but then a restriction in old age (Barker and Wright, 1955) This restriction has also been noted in a converse way in a study of social contacts within the

respectively, 95, 41, and 78 (Sweetser, 1941)

In total, the data presented in Figure 3 emphasize that, though goals may shift, the tangible evidences of expansion are most obvious during the developmental phase of life Expansion in young adulthood in terms of concrete *products*—children, work, specific and recordable achievements—is accomplished through relatively direct personal manipulation and mastery of the environment, in old age overt evidences are less frequent, and much of the sense of continued significance and worth seems to be achieved indirectly or vicariously via *identification and fantasy* Related to this observation is Strong's finding (1931) that young professional men were interested in advancement, whereas older men were less interested However, older men more than younger men believed they could "put drive into the organization" and stimulate ambition in associates The latter suggests that, although *personal* striving may become less important with age, one may value this trait no less but may achieve satisfaction of this drive by indirect means

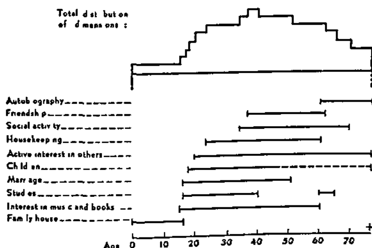


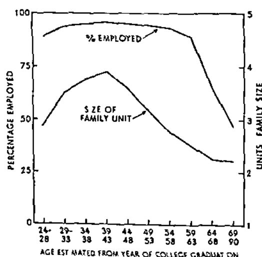
FIG 2 —Expansion and restriction in life-activities during the course of life as illustrated in the life of Elizabeth Textor Goethe 1731–1808 (From Frenkel Brunswik 1936)

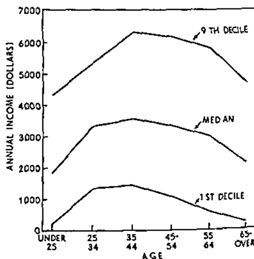
NEGATIVE ORIENTATIONS, DEFENSES AGAINST LOSSES, BASIC FRUSTRATIONS

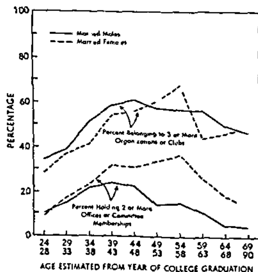
Although the matter of aging can best be understood in the context of the total life span, the basic concern of this volume is

with the restrictive years, with the years of decline, of loss of significant role, withdrawal from activities The restrictive phase of life is probably initiated by a variety of factors children mature and leave home, abilities decline, energies wane, friends and associates begin to die off, and cultural biases against age begin to be asserted If, as discussed above, there is a strong need for "expansion" and orientation toward the future dominating human life with the tangibly evident results most apparent in the early years, a parallel need, becoming increasingly important as age advances, is that of erecting defenses against the anxiety generated by physical and social losses By and large, these "defenses' involve avoidance or protective behavior and thus may be thought of as essentially negative The postulation of these two broad "needs"—one a positive force, the other a negative force—serve, in the present writer's opinion, to relate in a meaningful way and to "explain" a wide variety of phenomena of aging

Wherein lies the threat of aging, the source of the anxiety against which defenses are necessary? First is the matter of







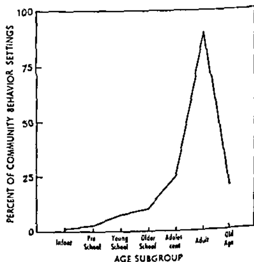


FIG 3—Expansion and restriction of the human life-cycle as illustrated in selected group data

valuing of age groups by the culture In the American culture youth seems to be glorified to get older, to move into middle and especially into old age means to move into a less highly regarded age group In middle-class society at least the "best years of life" or the years described with most favorable adjectives, seem to be the forties (Liccione 1952 Tuckman and Lorge 1952) Getting older beyond these years implies a general loss of status—a loss that is translated quite tangibly into biases such as those against hiring middle aged and older workers (Cassidy 1944) the establishment of a relatively fixed retirement age and the enforcing of other limitations e g the attitude documented by one study that beyond a certain age people should not engage in certain activities (Havighurst and Albrecht 1953) Reference was made earlier to Murray s (1938) concept of press a construct which includes the potentiality of the environment to satisfy needs. As one moves into older age categories—especially as he shifts roles from employed to retired from married to widowed —he finds an environment not only with reduced potential for providing satisfaction of numerous needs but one that actually is in certain respects negative in a threatening and restrictive sense

Quite aside from possible general losses in status, one may experience special culturally generated problems because of the ambiguity involved in shifting from one age role to another Lewin s analysis (1939) of the behavioral consequences of the adolescent s being in overlapping fields and having the status in a sense of a marginal man seems equally applicable to many of the problems of aging Uncertainty of role is likely for example to characterize the person nearing the age of retirement who is uncertain as to whether he is already viewed as being retired or is expected still vigorously to voice his views at staff meetings In terms of individual differences a strong case may be made for a flexible retirement system but the ambiguity the uncertainty as to actual retirement date will likely generate anxiety and the threat to self concept may be great especially if one is retired while one s colleague is viewed as worth an other year or two The ambiguity of role that faces the older person who has come to live with his married offspring can hardly help but generate anxiety and provoke defensive mechanisms

Biological decrements—in reaction time strength sensory acuities sexual capacity —not only reduce the older person s capacity to deal effectively with his environment and to achieve gratifications in accustomed ways and to accustomed degrees but such changes also constitute an anxiety generating threat since they represent *losses* that herald the onset of what may be viewed as an irreversible trend While widely studied in themselves biological losses have not yet received the attention they deserve from the point of view of the way in which they are perceived by the individual There is reason to believe that over a broad range of adult years the status losses such changes imply (even those such as graying or loss of hair which have no evident functional significance) and the consequent threat to self may be as or more significant psychologically than any actual diminution in functioning capacity

The achievement and maintenance of good adjustment require the potential of mobility a certain freedom on the part of the individual to move out of a threatening or frustrating situation into one more satisfying or at least less threatening But as age increases commitments and investments also increase The responsibility of children the financial burdens of middle age the investment of time and money in training the accumulation of specialized knowledge and skill as well as seniority and salary level—all these things coupled with reduced opportunity because of society s bias toward employment of older people or because of the paucity of positions of appropriate specialization and level often result in the older man s having to remain in an unpleasant threatening situation where-

as the younger man without commitment and responsibility can more readily move

Still another variable that introduces frustrations into life and tends to pinpoint threats at specified age levels is that of changing time perspectives In the American literature Frank (1939) was among the first to stress this variable though Lewin (1946) Buhler (1952) Billings (1949) and Kuhlen (1956) have also emphasized it This variable largely neglected by psychologists who have tended to concern themselves with limited segments of behavior over limited time periods may well be one of the major variables distinguishing old age from middle age middle age from young adulthood and young adulthood from adolescence Perhaps in the late thirties comes a realization that time is finite and that the future is not limitless as the adolescent views it When this awareness—the sense that time is finite and in certain respects already beginning to run out—first arises there is likely to be concern about the matter of expansion and possible restriction The basic finiteness of life expectation may especially concern the old but the sublimits set by culture or biology may pose threats of aging during the course of adult years The unmarried woman of 30 senses that time is running out that she may be getting *too* old the childless woman of 40 who wants children may feel the urgency of biological time the parents in their forties whose children are of an age when they will soon be leaving home sense the shortness of time to accomplish for their children the things they want the man in his thirties or forties who has not yet achieved his vocational goals may feel time is of the essence and it is difficult for old people to remain oriented to the future when they realize that in absolute terms their time *is* limited In a sense under these conditions the future becomes *now* Goals are likely to become more specific, day by day activities toward those goals more significant and self evaluations more realistic In old age because of absolute limits on the future there may be a resigned apathy rather than anxiety, or a tendency to orient toward the past via fantasy rather than toward the future

In view of these considerations it may be anticipated that psychological, sociological and physiological factors might well combine in such a way as to produce problems of adjustment characteristic of particular age groups Havighurst (1953) has discussed this matter more comprehensively than other writers in reference to the concept of developmental tasks, pointing out that each decade of life involves special adjustment problems that must be mastered if subsequent adjustment is to be optimal Among the developmental tasks of middle age proposed were achieving adult civic and social responsibility, establishing and maintaining an economic standard of living, assisting teen age children to become responsible and happy adults developing adult leisure time activities relating one s self to one s spouse as a person accepting to and adjusting to the physiological change of middle age and adjusting to aging parents In the more detailed descriptions of these tasks' reference is often made to last opportunity,' 'never reach the peak and various negative physical changes But the suggested developmental tasks of old age more specifically imply adjustment to losses They include adjusting to decreasing physical strength and health adjustment to retirement and reduced income, adjusting to death of spouse, establishing explicit affiliation with one s age group meeting social and civic obligations, and establishing satisfactory physical living arrangements

The emphasis upon *protection* and *conservation* of gains made earlier seems to characterize the motivational patterns of old people the world over Simmons (1946) has studied data from a wide variety of cultures and has hypothesized that the following five goals are rather generally held by old people

1 To live as long as possible at least until life satisfaction no longer compensates for its privation or until the advantages of death seem to outweigh the burden of life
2 To get more rest relief from the necessity

of wearisome exertion at humdrum tasks, and protection from too great exposure to physical hazards—opportunities, in other words to safeguard and preserve the waning energies of a physical existence

3 To remain active participants in personal and group affairs in either operational or supervisory roles—any participation, in fact, being preferable to complete idleness and indifference.

4 To safeguard or even strengthen any pre rogatives acquired in long life, i e, skills, possessions rights authorities, prestige, etc

5 Finally, to withdraw from life, when neces sity requires it, as honorably as possible without too much suffering and with maxi mum prospects for an attractive hereafter

In total, it may be argued that the re strictive phase of life, with its attendant threats and need to protect and conserve, has the effect of generating anxiety, especially when the threats are made explicit—that is, when the job is *actually* threatened, demands actually made—and thus serve to evoke defensive maneuvers of one kind or another It remains to be seen in data to be discussed below whether in fact anxiety *is* increased, whether susceptibility to threat does become greater, and whether behav iors that may be viewed as defensive be come more common

LIFE A LONG-TERM PROCESS OF ADJUSTMENT

Developmental psychology is concerned with long term processes and long term outcomes While the general psychologist is likely to concern himself with the dynam ics of a brief episode in the life of an individual and to consider the adjustment process in terms of day by day adjust ments, the developmental psychologist is likely to be concerned with more comprehensive "acts," broader units of time, and a world infinitely more complex than that found in the laboratory

A number of writers have taken the 'long view" Buhler (1933, 1951) has emphasized that each individual life seems to have a fundamental "ground plan" and has recently (1957) reaffirmed her view that the most promising approach to the study of the life span lies in examining over all life-goals and the progressive setting of goals in the lives of individuals The editors of the *History of Psychology in Autobiography* (1952) noted in the Preface to that volume that the lives described therein are most significantly differentiated in terms of the degree to which they are given unity by a persistent and pervasive goal orientation And Murray (1938), in whose personality theory needs occupy a central position, suggests that the basic unit for psychological study is *the life span,* but he notes that the unwieldy character of this ideal unit forces investigators to study relatively short term need press units

Buhler (1933) and her associate Frenkel Brunswik (1936) are among the few who have not been overwhelmed by the unwieldy character of this large unit. Having examined biographies and autobiographies of a large group of individuals and having noted the regular pattern of expansion and restriction, they have hypothesized that lives can be characterized in terms of a series of adjustive phases (The following descriptions have been paraphrased slightly from Frenkel Brunswik, 1936)

The *first phase* is the childhood phase, in which the child lives at home and has relatively narrow interests confined mainly to school and

[illegible]
and independent activity or by an independently acquired personal relationship This is a period of expansion ' but it is primarily ex

beginning of this period In the main interests are unspecified

The *third period,* beginning at about age 28, seems to be clearly defined in its onset by definite choice of occupation (about 69 per cent of the cases) and with a definite personal tie and establishment of a home (about half the cases) This period, lasting until about 50, was viewed

by these investigators as the culmination period the period of the largest number of dimensions the period of best professional and creative work and the time of most numerous personal relations This is a period characterized by di rection and specification of activities (It may be added parenthetically by the present writer that Lehman s studies of age and achievement [1953] place the peak period of productivity in terms of either quality or quantity of output in this same period roughly from 30 to 40 years of age In terms of productivity of sufficiently noteworthy character to become a matter of public record patents scientific contribu tions literary productions various factors such as ability drive and experience and train ing seem to combine optimally in the period designated in the above description as the culmi nation period of life)

The *fourth phase* beginning on the average in this group at 48 5 years is ushered in by the appearance of negative dimensions Losses which are uncompensated by new gains appear This is a transition period of evaluation of life and progress thus far with possible emergence of new efforts to achieve that which had not yet been accomplished But also at this age appears a tendency to change occupation to discontent and to negation. Trips for health and rest are more frequently taken between the forty fifth and forty eighth year At the beginning of this period artists tend to destroy their own creative work.

The *fifth period* is ushered in at an average age of 63 8 and is often introduced by complete retirement from profession and from any sort of work (in 64 5 per cent of cases) sickness [illegible] loosened the ties and has given up the plan of life which he has built for himself This is a period of retrospection of drawing up the bal ance sheet of life of considerations about the future about oncoming death and one s past life Religious questions may arise Age is likely to be mentioned as are complaints of loneliness

This analysis is based upon life-histories obtained in the German culture If such phases of life-adjustment are found in oth er cultural settings it is likely that the critical ages will differ from those specified above and that the content of the vari ous phases may differ Although this type of analysis is fairly subjective, such begin nings would seem necessary to the develop ment of a psychology of life-span adjust ment. This conception of the life span sug gests hypotheses as to ages when goal re-orientations occur, when certain needs may become stronger, when life-adjustment may be improved or may deteriorate Super (1957) has found it useful as a frame of reference in which to attempt to build a ' psychology ' of careers

HYPOTHESES REGARDING THE RELA TIONSHIP BETWEEN AGE AND ADJUSTMENT

Considerations presented thus far in this chapter permit the formulation of a number of general hypotheses regarding the rela tionship to be found between age and vari ous symptoms of adjustment and malad justment. The basic consideration in such hypotheses is the degree to which the total circumstances surrounding a particular phase of life offer opportunities for grati fication of needs or pose threats, conflicts and frustrations

The over all pattern of expansion and restriction in life leads to the inference that everything considered, the relationship be tween age and adjustment is generally cur vilinear As long as positive gains to the hoped for degree are present there should be improved or continued good adjustment. When developmental losses which are per ceived as significant in terms of individual values *begin* to appear, scattered anxieties about aging may arise But when losses outweigh gains, anxieties and other evi dences of poor adjustment may become general Since this general hypothesis re-lates to a gross *over all* evaluation it might be anticipated that the most relevant evi dence would be found in over all ratings as, for example ratings of general happi ness

The foregoing hypothesized trend may not be evident in *all* types of symptoms of adjustment. During the course of life peo-ple tend to seek out a niche that fits their

abilities, interests, and personalities (thus is non threatening) and tend also to erect defenses against anxiety, with the result that, although general happiness may be rated lower, manifest symptoms of anxiety may *total* about the same, age for age, over a long period of adult years, but with different types of problems generating the anxiety at different years A second hypothesis, then, is that under *normal* conditions there will be no particular increase with age (and may, in fact, be a decrease) in *general* symptoms of anxiety as these are enumerated in typical surveys but that there will be age trends with respect to anxiety generated by particular adjustment areas, with these adjustment areas waxing and waning at *different* ages in their potential for generating stress

A third hypothesis relates to adjustment under stress Since older adults tend to find themselves in more precarious positions physically and socially, they will also be in more precarious positions psychologically and will evidence this state of affairs by being more susceptible to stress and threat Though the gains typically made well into the adult years may be expected normally to lead to better adjustment and improved self concept, the *consequences of disruptions* of life (through death divorce, loss of job) nonetheless would appear to become increasingly serious, as commitments to family and occupational role are solidified

years the peak of expansion noted in Figure 3 and may, in fact, be at the very beginning of adulthood, *before* commitments and responsibility in connection with profession and family are great

The foregoing expectations regarding the relationship between age and adjustment may not, of course, hold for particular individuals or groups While certain generalities may hold for people *in general* within a given culture, the course of aging is largely an *individual* matter Individuals may be expected to vary in the ways they perceive various so called crises of aging, in the degree to which life up to the point in question has been accompanied by success or failure in the nature and timing of the situational factors (e g , role changes) that characterize their particular lives, and in the nature of their self concepts and age identifications All such conditions must be taken into account when examining or predicting the age pattern of adjustment of particular individuals or particular groups

Buhler (1935) for example, has noted that the 'psychological' curve of life conforms rather closely to the biological curve for those individuals whose activities and values emphasize the physical Thus the athlete and the narcissistic woman may be expected to feel the threat of age earlier People such as manual workers, whose effectiveness depends upon physical capacity but not in such a crucial way as is true of athletes may be expected to feel aging threats somewhat later And people whose lives emphasize "mental" values, whose rewards are found in more general contributions professional activities, and the like have "psychological life curves" that markedly lag the biological curves For them the threats of aging may come very much later Occupational groups vary in

and those with high achievement needs but who have been successful would find the forties less threatening than would those who want to achieve but have not and sense that time is running out Since desire to marry is rather general, single women may be expected to differ from married women in the degree of stress experienced around the age of 30 (Kuhlen and Johnson, 1952), when time for them is running out Differing socioeconomic groups vary in the degree to which and the point at which age brings stress, as do also the sexes It has been noted that adjustment to a typical aging crisis—retirement—will depend upon the meaning of work and re

tirement to the individual (Friedman and Havighurst, 1954) and presumably, the meaning menopause has to the particular individual will be a determiner of that individual s reaction to the situation

In general then it would be expected that there will be for certain groups not an over all curvilinear relation of adjustment to age but rather a cyclic sort of relationship with various factors having the effect of making certain periods of life especially satisfying concentrating symptoms of maladjustment at certain ages, heightening motivation in an already existing direction or producing a reorientation of motives

How people react to frustrating or threatening situations depends also upon how they have previously reacted upon their adjustive predispositions upon their *pre existing personality patterns* Their own and other analyses of the psychoses of later maturity led Sands and Rothschild (1952) to propose a "socio psychiatric" theory of reactions to aging which emphasizes social and organic *interactions* As a result of studies of various psychotic groups and an elderly non psychotic group of males, these investigators suggested that "the pathologic reactions of the kinds described are products of the special vulnerabilities of given personality types in reaction to certain sociopsychiatric stresses and in the presence of organic cerebral disease " A simplified scheme of their analysis of the psychoses of later maturity is reproduced in Table 3 Although relating to the psychoses, the same point may be made regarding less pathological reactions to the stresses of aging How a person will react will depend not only on the degree of stress but also upon pre-

TABLE 3*

HYPOTHESIZED INTERACTION OF PREMORBID PERSONALITY EXTERNAL STRESS AND ORGANIC DAMAGE IN THE PRODUCTION OF PSYCHOSES AT VARIOUS AGES IN LATER MATURITY

Group	Premorbid Personality	Age Period and Reaction to Stress			
		50 60	60–70	70 80	80 90
I Involutional psychoses	Egocentric object relationships rigid adjustment patterns sensitive dependent	External stress high psychosis			
II Psychoses with cerebral arteriosclerosis	Many show marked lability of emotional reactions instability of adjustment techniques aggressive and demanding	Stress average	Stress average plus organic damage psychosis		
III Senile psychoses	Like involutional group though less rigid	Stress minimal	Stress minimal some organic damage	Stress average organic damage increased psychosis	
IV Non psychotic senile	Easygoing wide range of interests without over attachment to objects	Stress average	Stress average organic deficit minimal	Stress average organic damage increased	Stress average general organic decline no psychosis

* Source After Sands and Rothschild 1952

existing personality and other factors Data presented later regarding typical personality changes with age are relevant to this issue

In the main, these latter considerations point to the need for hypotheses and research dealing not so much with *over all age trends* in adjustment for heterogeneous groups of the populations as for more careful consideration of the factors involved in adjustment and how those factors vary with age and interact in psychologically meaningful and relatively homogeneous subgroups of the population At best chronological age is only a convenient means of ordering developmental data it may be that greater precision can be obtained and more meaningful relationships established if a search is made for other age related independent variables Illustrative of alternative and possibly more fruitful ways of arranging developmental data is a study by Lansing and Kish (1957) They proposed that the family life-cycle may be a more significant independent variable in studying aging effects than is chronological age A variety of circumstances and behavior (such as buying a new car, having an employed wife owing debts, owing own home) were related in this investigation to (*a*) chronological age and to (*b*) stages in the family life-cycle In all instances the relationship to age was represented by a relatively smooth unimodal curve, whereas in a number of instances bimodality appeared when comparisons were to stages in the family life cycle For example, married women *without* children and married women with *older* children are more likely to work outside the home and families in these stages are also more likely to have bought a new car Homeownership declined only very slightly in the 'over 65 group but had a marked drop in the final life-cycle stage of widowhood While the variables studied were only illustrative the point is well taken that in the study of other variables including psychological adjustment variables age role changes characterizing the life cycle should be adopted more widely as an independent variable in place of or parallel to chronological age

III Empirical Evidence Regarding Age and Adjustment

From general considerations regarding the relationship between age and adjustment attention now shifts to the empirical findings In general the data are of four types (*a*) evidences of happiness and contentment (*b*) evidences of losses in self concept (*c*) evidences of anxiety and susceptibility to threat or stress and (*d*) scores on general tests of adjustment which include not only items relating to anxiety and feelings of well being but also items relating to other types of behavior commonly thought by psychologists to be symptomatic of good or poor adjustment The question now relates to the degree to which the facts support the expectations outlined in the preceding paragraphs

Age Trends in Happiness

When individuals are asked to rate *present* happ ness their ratings apparently bear no strong relationship to present age according to a study by Watson (1930) involving several hundred graduate students ranging in age from 20 to over 60 But ratings of various ages *in retrospect* do suggest a relation of happiness and age Such retrospective evaluations of life happiness are of course open to the same criticism that may be leveled against any life history method depending upon recalled facts or judgments Whether an event is recalled for example and the emotional tone associated with it upon recall will likely be dependent upon, among other things, the emotional response to the event when it occurred, the nature of intervening experiences, and the nature of present circumstances. And the same may be said for the periods of life in which these events occurred But nonetheless, a request for retrospective evaluations com

paring one age period with another, at least has the merit of giving the individual a comparative frame of reference in which to evaluate various periods of life

Two studies (Morgan 1937, Landis, 1942) in which older adults were asked to indicate which of several specified age periods were happiest yielded almost identical results, as indicated in Table 4 The young adult years (25–45) were so designated by approximately half of each sample Although almost half of the subjects queried by Cavan *et al* (1949) reported all periods of life to be equally happy

TABLE 4

PERCENTAGE OF INDIVIDUALS OVER 65 WHO IN RETROSPECT DESIGNATED VARIOUS PERIODS OF LIFE AS HAPPIEST

Period of Life	New York Sample*	Iowa Sample†
Childhood (5–15 years)	14 5	11 1
Youth (15–25 years)	18 9	19 3
Young adulthood (25–45 years)	49 1	51 4
Middle age (45–60 years)	12 4	5 8
Later life (60 and up)	5 1	4 7
Undecided or no data		7 7
No of cases	370	450

* Source Morgan 1937

† Source Landis 1942 Exact figures were provided by Dr Landis in a personal communication

about half of those who designated an age also selected young adulthood in this study the age range of 20–40 years A study by Kuhlen (1948), published only in abstract, utilized a rating procedure in which each subject was asked in interview to chart his happiness (in effect, to rate happiness for each successive year) during the course of his life thus far The age of peak happiness for married men and women was in the 25–29 age range and for single women in the 40–44 age range, the three "peaks" thus falling within the 25–45 age range reported as happiest by the Morgan and Landis subjects

In the study just cited, a steady though somewhat irregular decline in mean happiness ratings was evident from young adulthood onward Data reported by Cavan *et al* (1949) show a similar decline in happiness, zest for life, and interest in life for a substantial group over 60 years of age In this instance evidence went beyond the single rating of "happiness", instead "scores" of happiness, zest, and interest were based on responses to from nine to thirteen questions Table 5 contains the relevant data for the age range 60–90 Here facts for over 90, though reported in the original source, are omitted because of the very small numbers of cases involved It will be seen that, although some irregularity in trend occurs, there is a general decline with age in percentage of individuals who have attitudes of happiness and who show "great zest" for life and an increase in the proportion who evidence lack of interest in life However, Morgan (1937) had earlier reported contrary results The upper third of her group in happiness (also diagnosed on the basis of response to several questions) was almost identical in mean age with the lowest third, the total sample ranging from 70 to 93 years of age

The decline in happiness thus evident does not, of course, imply that old age is generally a period of unhappiness Indeed, facts are strongly to the contrary Morgan (1937) had also asked her subjects (all over 70) to rate the degree to which they enjoyed life now Twenty six per cent said "Very much", 30 per cent, "Considerably", 19 4 per cent, "Somewhat", and 24 4 per cent, "Slightly" or "Not at all" Thus even in old age the majority of subjects report substantial happiness This finding has been confirmed by Havighurst and Albrecht (1953), who reported that "a good third of older people are as happy in their later years as they have ever been," and by Cavan *et al* (1949)

Despite criticisms that may be leveled against self judgments of happiness, and there are many, such subjective evaluations may be presumed to reflect to some degree one of the major facets of adjust

ment. It will be noted that happiness as evidenced in *over all* judgments bears a relationship to age not unlike the *over all* curves of expansion restriction presented earlier This particular facet of adjustment thus seems to conform to expectations de scribed in the first hypothesis above, namely, that the most general relationship of adjustment to age will be curvilinear over the whole adult life span Kuhlen s data seemed to suggest that "peak" happiness occurs prior to the years of the so-called culmination period described by Buhler This is likely because the two outstand ingly happy events of life as evidenced in this interview study—marriage and birth of first child—occur typically in the twen ties It is probable that the *onset* of both happy and unhappy or threatening episodes or periods of life may elicit greater degrees of happiness or anxiety, respectively, than will characterize the subsequent course of the episodes

CHANGING SELF CONCEPT

By self concept is usually meant self regarding attitudes, one s concept of his own personal worth, the degree to which an individual is satisfied with himself and is self confident Evidences of changes in the self concept are often indirect, but, in total, the data seem to suggest that con sciously or unconsciously the individual, as he gets older, has a less positive attitude toward himself In the most comprehensive effort to measure self regarding attitudes made thus far, Mason (1954) found that on several measures a group of institu tionalized indigent old people had more

TABLE 5*

PERCENTAGE OF INDIVIDUALS AGED 60–90 WITH GIVEN ATTITUDES OF LIFE SATISFACTION

Attitude Indicated	Age Period					
	60 64	65 69	0–74	75–79	80–84	85 89
	Males					
Happiness	42	44	38	33	33	40
Usefulness	84	71	82	74	71	50
Great zest for life	49	47	38	39	44	19
Lack of interest in life	4	12	13	10	5	17
Median adjustment score on Attitude Inventory	52	50	53	52	51	48
Total no of cases†	74	92	118	121	63	21
	Females					
Happiness	40	38	27	26	17	21
Usefulness	88	73	71	68	58	41
Great zest for life	43	39	35	41	26	18
Lack of interest in life	6	14	10	19	11	25
Median adjustment score on Attitude Inventory	52	51	50	50	44	43
Total no of cases†	152	163	185	135	72	34

* Source Cavan *et al* 1949

† Totals are for the entire group For any one item totals might be slightly smaller

negative self concepts than did a group of independent middle class oldsters and that both, in turn had more negative self concepts than did a more youthful low economic group However individual differences among the old groups were greater than among the young indicating that reactions to the aging process vary among individuals The same age trend was noted by Sward (1945) who gave intelligence tests to younger and older college professors and recorded the comments that his subjects made The older group made twice as many self belittling comments than did the younger men Again the variability was much greater among the old

Utilizing a "draw a person" test Lehner and Gunderson (1953) found that men tended to draw larger figures the older they get up to about age 30 and thereafter to draw smaller pictures Women drew larger pictures up to age 40 and then smaller pictures Since it is often assumed that in such picture drawing the individual projects his "self image' it possibly may be inferred that these trends reflect trends in self evaluation that the picture is drawn larger until the individual senses that he has passed the prime of life In other studies, Lehner and Silver (1948) and Giedt and Lehner (1951) asked subjects to draw a person and then to label the age of the person drawn Subjects under 25 tended to record ages older than their own, while those over 25 recorded younger ages Ages slightly older than these were recorded by neuropsychiatric patients These results were interpreted as suggesting that approximately age 25–30 is the idealized age in the American culture That increasing age may be threatening to one's self concept, especially for women, is also suggested by Norman's finding (1949) that older women especially single women, more often failed to record their date of birth in biographical sources Fortunately, their willingness to record data of Bachelor's degrees made such analyses possible

Age trends in expressions of self confidence (usually assessed by multiquestioned paper-and pencil tests) are not well established In a recent longitudinal study Kelly (1955) found a reliable gain in self confidence from the twenties to the forties in the case of women but no change in the case of men Brozek (1952), in a cross sectional study, found evidence in the direction of increasing self-confidence among men around 50 compared to men in their early twenties but generally poorer emotional adjustment This increase in self confidence during the expansive years makes sense, but what of the years beyond middle age? Certain data of relevance to this question (anxiety symptoms, neurotic inventory results) are cited below, but few data described as relating to "self confidence" exist

It has often been said that a person is as young—or as old—as he *feels* Such age identification reflects self-concept, and it is of interest that in rather advanced ages—say, over 70—some individuals still describe themselves as "middle aged" while others describe themselves as "old" or "elderly" In one sample of 1032 subjects, only one person below 60 classified himself as "old" (Tuckman and Lorge, 1954) About half of over 300 individuals 70 years of age and over described by Phillips (1957) still identified themselves as middle aged In the sample studied by Kutner *et al* (1956), somewhat over two thirds of those in their sixties viewed themselves as middle aged, whereas about the same proportion of those over 75 viewed themselves as old or elderly

EVIDENCES OF "NORMAL" ANXIETY AND WORRY

The hypothesis was earlier advanced that under "normal" conditions no or only a slight relationship would obtain between age and anxiety, since adults tend to select mates, jobs, and other environments that are congenial and non anxiety evoking It might be anticipated that people would, in fact, become *better* adjusted with the passage of time—as long as life proceeds along

usual channels The facts, though sparse, seem to support this hypothesis The age incidence of "nervousness" in one health survey was reported by Britten (1931) Women evidenced nervousness more than did men at all ages, and, though the decrease with age was not precipitous, older individuals reporting nervousness were relatively fewer than young adults Hamilton (1942) reported that in his psychiatric practice individuals in their thirties, forties, fifties, and sixties were about equally represented among a sample of 200 who sought assistance for "nervousness"

Within these trends for "normal living" various normal problems (sources of anxiety) may wax and wane, but, since they arise at different ages, they may not disturb the age trend just described It is only when they are of great magnitude, or when many different worries are bunched at one age period that over all increases in anxiety might be expected at a given age Kerr *et al* (1949), Van Zelst *et al* (1951), and Dykman *et al* (1952) have reported a number of surveys of worries of adults and the ages at which they seem most prominent Results presented in Table 6 indicate that different ages are typified by different problems but that there are great individual differences Since the subjects were in the employment age range, the worries and problems characterizing the old did not appear in the tabulations, but indications of worries relating to the declining years appeared in responses of a group of trade union leaders (Van Zelst and Kerr, 1951) At ages 50–55 the two most commonly reported worries related to work efficiency and death, with health worries being quite common Kuhlen (1948) found that major unhappy episodes of life tended to be associated with bereavement, ill health in self or others, financial problems, and occupational difficulties When sources of unhappiness were distributed by percentage among causes, 10 per cent or more fell in these categories for one or more sex marital groups

TABLE 6*

REPORTED AGES AT WHICH VARIOUS TYPES OF WORRIES CHARACTERIZED BUSINESSMEN AND PSYCHOLOGISTS

Source of Worry	Per Cent Expressing Worry		Median Age		Interquartile Range	
	Businessmen	Psychologists	Businessmen	Psychologists	Businessmen	Psychologists
	59	52	27	20	18–38	16–31
	34	54	26	23	19–39	18–30
	40	65	25	26	19–35	19–39
	37	88	33	26	22–40	21–41
	80	91	35	30	26–47	23–38
	†	63	†	31	†	26–38
Job security	74	75	39	32	28–45	26–38
Peace of mind	†	67	†	35	†	26–47
Political convictions	56	82	44	38	36–53	29–48
Health	69	57	39	38	21–49	28–50
Giving up important hopes and ambitions	35	56	30	40	24–45	28–45
Marital difficulties	44	42	39	41	31–47	34–48

* Source Dykman *et al* 1952

† Absence of data results from the fact that certain items were not included in all phases of the investigations

Turning now to tension areas in old age, a study by Olsen and Elder (1958) is unique among published gerontological studies (though the procedure has been used with adolescents) in that a more ob

jective measure was utilized in defining tension areas reaction time and free associations to words representing different areas of adjustment In the 60–80 age group of women compared to the 30–40 group problems of finances health death and religion seemed especially great Morgan (1937) had earlier reported the following percentage distribution of worries for a group of old age pensioners over 70 years of age financial worries and dependence 48 per cent concern for spouse and family 21 per cent poor health and physical dependence 18 per cent unable to work 6 per cent family relationships estrangements etc 5 per cent death 1 3 per cent Havighurst and Albrecht (1953) report that their sample of older men were most concerned about still being a part of things going on and still being of use to those about me Older women were most concerned about being able to take care of myself and still being of use to those about me While available studies in no sense establish in any definitive way the problems and anxieties of older age groups they do illustrate that special types of tension areas characterize the various ages and constitute the type of empirical data which specify to a degree the developmental tasks of maturity and old age that Havighurst describes

AGE AND SUSCEPTIBILITY TO STRESS AND THREAT

Studies of the physiology of aging indicate that aging losses are often not evident under conditions of normal functioning but become clearly evident when an organ system is subjected to stressful loads An analogous situation may be expected in the psychological sphere Evidence slight as it is presented in the foregoing

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to increase with age Do such symptoms increase under conditions of stress as the physiological analogy suggests? Or put another way, are older individuals more susceptible to psychological stress or threat? Evidence points to an affirmative answer to this question It is commonly noted for example that older subjects are less willing to participate in psychological studies Although it is a reasonable inference that this is at least partly due to the threat implicit in intelligence and other testing investigators have not often offered relevant evidence Welford (1951) however has been quite explicit in pointing out that he experienced greater difficulty in persuading subjects over 30 to participate in a motor learning experiment and that when they participated they were notably more anxious than those younger about the quality of their performance

Kuhlen (1951) reported the results of a survey of frequency of nervous symptoms among enlisted naval personnel in a World War II pre embarkation center awaiting transportation to Pacific combat areas Age trends were studied for three groups on the assumption that those who had not yet been overseas would find this situation less stressful that those who had been overseas previously and in actual combat would find an impending return to combat most stressful and that those with previous overseas but no combat experience would find their present situation stressful to a degree between the other two groups Table 7 shows the results in terms of the mean number of symptoms out of 20 presented in a forced choice test situation It is clear that those presumed to be under most stress reported most nervous symptoms and that the degree of relationship between frequency of nervous symptoms and age varied somewhat with the degree to which the several groups were presumed to be under stress A special finding relates to the point made earlier (cf p 867) that degree of response to threat will be related to degree of commitment to family In this study, under the stress of war unmarried men evidenced fewest symptoms of nerv

ousness,' married men without children the next highest number, and married men *with children* the largest number of nervous symptoms The number of subjects in this study was large, and the trends and differences just cited were statistically reliable

In a more recent study (Olsen and Elder, 1958), it was found that, in a laboratory type situation involving reactions to a free association test, older women between 60 and 80 showed greater evidences of emotional disturbance in reaction time and responses to emotion provoking stimuli than women between 30 and 40 Since laboratory type situations may be viewed as being somewhat threatening to older subjects, these findings may also be interpreted as showing increased anxiety with age under conditions of stress

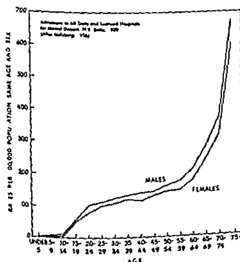
More striking evidence of the greater susceptibility of older adult groups to psychological stress is to be found in rates of suicide and admission to hospitals for the mentally ill on the assumption that these psychopathological states or outcomes are triggered by stressful situations A previous chapter has dealt with the matter of the psychopathology of aging but over all age trends for mental illness and suicides are presented in Figure 4 Mental illness rates climb strikingly in older age brackets for both sexes, and suicide rates climb rapidly

TABLE 7*

MEAN NUMBER OF NERVOUS SYMPTOMS FOR EACH AGE GROUP FOR THREE GROUPS OF ENLISTED NAVAL PERSONNEL VARYING IN DEGREE OF STRESS

EXPERIENCE GROUP	AGE GROUP					
	18–20	21 23	24 26	27 29	30–32	33 35
United States only	3 2	3 9	4 5	5 0	5 3	5 3
Overseas non-combat	4 8	5 0	5 8	6 1	6 9	8 2
Overseas combat	6 0	6 2	6 6	7 2	8 2	8 7

* Source After Kuhlen, 1951



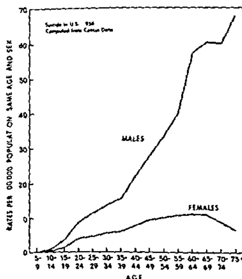


FIG 4—Increasing susceptibility to stress with age as reflected in rates for suicides and mental illness

in the case of males though not in the case of females In the instance of suicides, evidence seems to suggest that rates are dependent upon the degree of stress under which various groups live and that the rates are altered as the degree of stress alters Thus women have neither the achievement needs nor the economic responsibilities of men and older men likely experience more frustration in the occupational area than do younger men Jones and Kaplan (1945) point out that during World War II when jobs were more readily available for old men suicide rates in this group dropped noticeably

In total then the available evidence relative to anxiety symptoms and response to threat supports the view that degree of anxiety varies little with adult age at least over the ranges studied as long as life is reasonably normal but that aging losses are evident when the individual is faced with threatening or stressful situations These findings parallel those found in the instance of physiological functioning Whether these trends are in turn dependent upon organic perhaps neurological decrements of some sort or are basically psychological in origin reflecting the more precarious psychological status of the aged and aging is not clear But whatever their origin it will be argued later in the chapter that these age trends are likely to play an important role in the generation of a wide variety of age changes in personality and performance Together the evidence presented in the above paragraphs comprises an important link in the data supporting a dynamic theory of aging

AGE TRENDS IN TESTS OF GENERAL ADJUSTMENT

A number of investigators have attempted to assess adjustment during the adult years by means of conventional paper and pencil tests Such tests are presumed to measure traits variously labeled 'neuroticism,' 'emotional stability," and 'adjustment," but they are omnibus tests, including not only items related to anxiety and feelings of well being but also items related to interests and general patterns of behavior in social situations As noted earlier, their validity for aging studies is seriously to be questioned

Age data derived from these measures turn out to be highly inconsistent Gundlach (1939), for example, failed to find any marked relationship with age of scores on a general test of emotional stability, but, interestingly enough, when the data were examined not in terms of age but in terms of the period in society when young adulthood was reached, certain seemingly meaningful age variations in the data were noted Thus more neuroticism appeared among groups almost all of whose maturity coincided with depression years but who were brought up in the 1920s Fewer high neurotic scores were apparent among those who had had time to become established as adults before the depression hit but who were too young to become involved in World War I This analysis suggests the importance of viewing age data relating to adjustment against a base line of cultural change as well as against the usual base line of chronological age, but few investigators have capitalized this suggestion of 20 years ago

Phillips and Greene (1939) administered the Bernreuter Personality Inventory to 143 women teachers and found among single women an initial rise in neuroticism until age 30 and then a decrease whereas among married women neuroticism scores declined steadily with age Peck (1936), utilizing the Thurstone Personality Schedule, and Boynton (1942), utilizing an instrument of his own making found evidence suggesting improved adjustment among older teachers Pintner and his associates (1937) failed to find a reliable relationship with age of Bernreuter scores for a group of deaf adults Simpson (1934) found no relationship between age and scores on the Thurstone Personality Schedule in the case of 252 adult prisoners

Willoughby (1938) explored relation

ships between age and neuroticsm as measured by the Thurstone inventory administered to a rather sizable sample He reported an 'N shaped' curve, of the type illustrated in Figure 5, for the several sex marital groups Although Willoughby was critical of the meaning of scores of older individuals derived from "neurotic inventories' which had been developed and keyed on the basis of responses of college age individuals, he nonetheless offered tentative explanations of the age trends evidenced in the figure He thought the increasing tension during the twenties might result from problems of a sexual family or economic nature, which by the thirties are perhaps fairly well solved resulting in improved adjustment until the middle forties (which, according to these data are the best adjusted years of life) with increasing maladjustment from that point onward as people began to encounter the problems of aging (It is to be noted in these and other data relating to adjustment that the period of the menopause fails to stand out as especially stressful) The general trend toward poorer adjustment in the more advanced years is evident also in the findings of Cavan *et al* (1949) wherein general adjustment was inferred from scores from an attitude inventory

Despite the inconsistency of these find [illegible] cyclic relationship to age (A curvilinear relationship may of course be responsible for low Pearsonian *r* s reported in some studies) Although the timing of high and low points in adjustment has obviously not been established with any precision a curvilinear or cyclic relationship is compatible with one of the hypotheses earlier advanced Here again it may be noted that the utilization of chronological age alone as the independent variable may actually obscure developmental changes in adjustment during the adult years, since this procedure may have the effect of averaging together "scores' on people of the same age but who are in psychologically very different roles or life-stages

INDIVIDUAL AND GROUP DIFFERENCES IN ADJUSTMENT

Some indication of the importance of this last point has already appeared in data presented in the last several pages And, as will be evident below, individuals grouped by role self concept socioeconomic status etc may in some instances, at least evidence trends contrary to average age trends

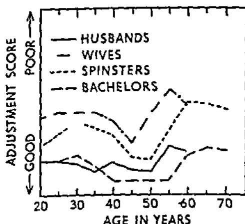


FIG 5 — Age trends in emotionality as reflected in scores on a brief test of psychological adjustment (From Willoughby 1938)

The relation of age identification (i e, self concept or self image) to personal adjustment has been demonstrated by Havighurst and Albrecht (1953), who report that felt age' was more closely related to measured adjustment than was actual age, and by Kutner *et al* (1956), who found that oldsters who viewed themselves as middle aged had higher morale than their contemporaries who viewed themselves as old Phillips (1957) has more systematically studied adjustment in old age in terms of role theory As a measure of maladjustment he utilized self reports regarding absent mindedness daydreaming about the past and thoughts of death, on

the assumption that such behaviors would not characterize well adjusted individuals (defined as those able to satisfy their needs) Individuals who had moved into less favored roles (e g were retired wid owed over 70 felt that they were treated differently) tended to be more maladjusted But a favorable age identification (i e identified self as middle aged) seemed ca pable of reversing this relationship between any *one* of the role changes considered and adjustment Thus *employed* oldsters who viewed themselves as old tended to be less well adjusted than were *retired* indi viduals who viewed themselves as middle aged When *two* role changes were in volved (e g retirement *and* widowhood) the effects of favorable age identification were not great enough to reverse the trend toward poorer adjustment This investiga tion incidentally is an excellent illustration of the potential fruitfulness of research on aging in which there is in contrast to usual descriptive studies some conceptuali zation in terms of more general theory In this instance age identification (self im age) was conceptualized as an intervening variable between age role change and adjustment

Different age trends for married and single women were suggested above in scores on a neurotic inventory In the in stance of single women it appears from various studies that the age of plus or minus 30—the age around which a reori entation from marriage to career seems to occur—is likely to be fraught with anxiety and tension Kuhlen (1948) found that the high point in happiness ratings was not reached by single women until some years after the peak for married men and women and Landis (1942) reported that whereas half of the married men and women indi cated the age 20–45 as the happiest and only one third indicated childhood and youth two thirds of the older spinsters identified childhood and youth as the hap piest period in their lives Thus is sug gested the emptiness of the adult years for individuals deprived of the basic happiness and varied gratifications found in marriage and family living Evidence of age trends in adjustment for different cultural or socioeconomic groups is sparse but if one assumes (as has been done throughout this chapter) that a fundamental consid eration in the determination of age trends in adjustment is the degree to which in dividuals of a given age experience threats or opportunities for need satisfaction then it would be anticipated that certain cul tural groups (e g , the lower socioeconomic groups) would show earlier and greater losses in adjustment with age Mainly the related lines of evidence consist of data suggesting that the lower economic groups experience early and increasing age asso ciated threats whereas upper socioeconom ic experience greater delay in such threats less loss or in fact long continued im provements in status Thus economic de pression threatens older low economic groups more than older high economic groups (Dublin and Lotka 1946) and low income groups experience a much greater decline in income with advancing age (Reder 1954) Simmons (1946) has suggested that technological societies may have created environments less conducive to good adjustment in old age than those characterizing many primitive groups

In Table 8 is presented illustrative evi dence suggesting socioeconomic and cul tural differences in one aspect of adjust ment—that of participation in community activities (Foskett, 1955) Degree of par ticipation for three age groups (21 34 35 54 and 55 and over) is shown for groups varying in income and in educa tional level For all groups there is a rise in participation from early to middle years But from the middle to the older years there is a drop for those of low income and those of low education whereas the high est income group showed further expanded participation in the older years and those of highest education showed only a min imal withdrawal Since income and educa tional level are related to age it is ap parent, also, that general age trends in

adjustment (as reflected in social participation at least) may reflect these differences as much or perhaps more than age differences This inference is supported by a study by Taietz and Larson (1956) of social participation in old age, in which economic and retirement status seemed more important than age as a factor in social withdrawal

IV Age Patterns in Personality Growth, Continuity, and Change

The term "personality' refers typically to the individual s need structure, to his reaction tendencies and to his adjustive predispositions Much of the descriptive data already summarized thus relate to personality There remains, however, a number of questions First, what is the potential for personality change during the adult life that is for how long may personality ' growth" continue? Second, what about continuity of development over the years? And third, what about certain personality patterns of types not yet considered in the chapter but seemingly characteristic of older people and related to their adjustment, namely, characteristics such as conservatism dogmatism, and rigidity?

Long Term Personality Growth and Continuity

Some years ago Allport in his well known book on personality wrote "There is one law to which there are no exceptions every personality develops continually from the stage of infancy until death, and throughout this span it persists even though it changes' (1937, p 102) But a little later in the same book (p 142), after quoting William James to the effect that by the age of 30 the character has set like plaster and will never soften again, Allport asserted that "the verdict is perhaps too pessimistic and overdrawn, for some personalities seem to change markedly after the age of thirty But *in principle the judgment is sound'* (p 143) (Italics mine) Symonds (1951) similarly grants the possibility of continued ego development throughout life, but he is also of the opinion that few people do so develop in the course of adulthood

Is there any evidence that personality may continue to grow? The major available evidence deals not so much with personality change per se as with changing circumstances which might lead to the expectation that personality changes had or would occur For example, investigations of social, civic, and political activities show

TABLE 8*

Mean General Community Participation Scores According to Age, Income Level and Educational Level

	Age					
	21 34		35 54		55 and Over	
	No	Mean	No	Mean	No	Mean
Income level						
Under $3000	29	1 8	40	2 6	74	2 1
$3000–$5999	162	2 6	193	3 2	58	2 5
$6000 and over	48	3 8	90	4 2	14	5 9
Educational level						
Grades I IX	47	1 3	124	2 3	107	1 9
Grades X XII	166	2 8	154	3 4	32	3 2
Grades XIII and above	32	3 8	51	5 8	15	5 4

* Source After Foskett 1955

a continually expanding pattern, in the sense at least that a larger percentage of individuals are participating, up to perhaps 50 years of age (Pressey and Kuhlen 1957) Presumably with a continuing expanding role may go significant changes in personality at least to the point where expansion ceases But in the main evidence that there is personality change well into old age is to be found in individual case histories and in reports of therapy with particular individuals It is of some interest that Freud was of the opinion that psychoanalysis in old age would be a rather futile undertaking because by then the personality was so rigid that no change could be expected this quite aside from the fact that there would be so much material to be worked through that it would be almost an endless task On the contrary, modern psychoanalysists who have ventured into therapy with older individuals have reported substantial success (Kaufman 1937 1940 Atkin 1940) (See also chapter xxiii on this point) Evidently even in fairly late maturity there can be important personality changes

Probably a major factor in determining whether personality growth continues into the adult years and into old age is whether or not something really important happens to the person The possibility should not be ruled out that significant situational changes may launch a person on what amounts to a new developmental phase at almost any age of life Most readers have probably known an individual who for example was dominated by a relative with whom he lived (perhaps a mother a spouse, or a sibling) until 50 60 or even 70 years of age and who when suddenly "freed' by the death of the dominating person, was able to expand in ways never before possible and became, as is said colloquially a "different kind of person" In a number of the case histories which the writer has assembled in connection with a study of age changes in happiness, marked differences occurred in the degree to which one phase of life might be characterized by extreme deprivation, frustration, and insecurity, while a much later phase of life was characterized by success, security, and an over all evaluation of high happiness Although no direct data are available, important changes in personality may be inferred to have occurred, and often these changes seemed to be in a positive direction and hence would be labeled "growth" If detailed longitudinal data were available on adults as are now becoming available on adolescents, it is probable that a fair number of instances of marked personality change, in some instances in the direction of improvement, would be found, just as marked redirections in development characterize some adolescent records

What about the long term *persistence* of personality trends, the other side of the coin so to speak? There appears to be a fundamental continuity in personality change—continuity in the sense that adjustive patterns once established tend to persist over long periods of years The evidence relating to the adult years is of two sorts First, there is a variety of studies in which people who make good or poor adjustment to various life crises or to new roles are compared with respect to preexisting personality traits and antecedent conditions Terman (1938), for example, showed that people who were happy in their marriages were people who were previously well adjusted and had histories of happy childhood and adolescence Havighurst and Albrecht (1953) report that those oldsters in their sample who were happy and well adjusted had been that way also in middle age, and Cavan *et al* (1949) have shown a low positive relationship between present (measured) adjustment and earlier (recalled) history of adjustment

variables have been investigated in the same individuals over relatively long periods of time Data over a *very* long period of time are practically non existent, though

Madorah Smith (1952) has reported a comparison of certain personality traits as rated in the same individuals in childhood and again 50 years later The subjects were six children in the same family, and ratings were based on diary material descriptive of them 50 years ago compared with ratings of present status Although the study is obviously inadequate in many respects, there was evidence of a considerable consistency of personality over the 50-year period

But most longitudinal studies in the adult years deal with young adulthood The studies which have been under way for some years at the University of California under the direction of Harold E Jones (1958) are now reaching the point where the stability of certain patterns of personality trends from adolescence into the thirties and forties can be studied So far the evidence indicates that for some traits very substantial stability exists, whereas for other traits correlations over a 16 year period approach zero In the study by Nelson (1954) previously referred to, a test retest correlation of 57 over a 14 year period was obtained in the case of measures of liberality conservatism Strong (1951, 1955) has reported a 22 year follow up of individuals previously tested in college with his vocational interest blank and reports an average correlation of 75 between interest profile patterns But Kelly's recent report (1955) of a 20 year follow up of a group of men and women first tested in their mid twenties has provided the largest published array of correlation coefficients dealing with personality variables Table 9 contains sample correlations relating to personal traits such as self confidence, masculinity femininity, and values Correlations show both short term (reliability) and long term stability of these traits These correlations cluster around 50–60 and are thus substantially lower than the correlations of 84 (men) and 90 (women) reported by Jones (1958), in the instance of mental abilities over a 16 year (ages 17–33) period

TABLE 9*

TEST RETEST CORRELATIONS AFTER 20 YEARS AS COMPARED WITH SHORT TERM RELIABILITIES IN THE INSTANCE OF PERSONALITY MEASURES APPLIED IN THE TWENTIES AND FORTIES TO THE SAME PEOPLE

Trait	Reliability of Score after Short Term Interval	Stability of Trait after 20 Years
Self confidence (Bernreuter)	86	61
Sociability (Bernreuter)	78	46
Masculinity femininity (Strong)	82	65
Interest maturity (Strong)	93	46
Occupational level (Strong)—males	88	62
Theoretical values (Allport Vernon)	71	51
Economic values (Allport Vernon)	72	50
Aesthetic values (Allport Vernon)	71	52
Social values (Allport Vernon)	57	32
Political values (Allport Vernon)	75	49
Religious values (Allport Vernon)	75	60

* Source Kelly 1955 Correlation coefficients as estimated from bar graphs in the original publication

In general, while the correlations reported by Kelly and others are fairly substantial (at least for psychological data) and may be interpreted as indicating a fair amount of continuity or stability, they are at the same time sufficiently low as to permit important shifts from one age to an-

other for a fair number of individuals In total Kelly evaluates his findings as follows

> Our findings indicate that significant changes in the human personality may continue to occur during the years of adulthood Such changes while neither so large nor sudden as to threaten the continuity of self percept or impair one s day to day personal relations are potentially of sufficient magnitude to offer a basis of fact for those who dare to hope for continued psychological growth during the adult years [Kelly 1955]

The interdisciplinary character of Jones's investigation revealed the complexity of the interrelationships among personal traits, biological factors and institutional and situational factors in the determination of stability or change from the teens to the thirties Thus for males early maturing was correlated around 40– 50 with later measures of social activity and of occupational status On the other hand traits associated with adolescent maladjustment were not clearly predictive of adult maladjustment suggesting that "the adaptive significance of a given behavior pattern can thus be interpreted only with reference to changing demands in the life situation" (Jones, 1958)

CONSERVATISM, DOGMATISM AND RIGIDITY IN OLDER YEARS

A number of related personality trends, not yet discussed but highly revealing of changes in adjustive predisposition, occur with increasing adult age For example, evidence from a substantial number of studies of the cross sectional variety indicates that older adults are more conservative than younger adults They do not like change, they cling to older ideas and are slower to adopt new ones, in morals, politics, and general living they are likely to be "old fashioned" rather than modern and liberal, they tend to view themselves as conservative Representative of studies showing the increase in conservation with age and documenting the above statements are those by Bean (1933), Strong (1931, 1943), Pollak (1943), and Hinshaw (1944) For a more extensive summary and discussion of the personality changes considered in this section see Kuhlen (1945) and Pressey and Kuhlen (1957) But these trends are not sharp Seldom is the trend strong enough to put the majority of the young on one side of an issue and the majority of the old on the other side (Pollak, 1943) While oldsters view themselves as conservative, they believe themselves to be more liberal than when they were young Though cultural change is thus suggested as the cause of such age differences, various theoretical considerations as well as studies showing that older people do change attitudes less than do youngsters with the passage of time (Lorge, 1939) or even when efforts are made to change them (Marple, 1933) lead to the conclusion that conservatism does in fact increase with age and that observed differences are not merely an artifact of cultural change

Second, older adults appear to become more dogmatic, if by dogmatism is meant the taking of emphatic positions on issues and holding to them Cantril (1946) has reported evidence of greater intensity in the holding of attitudes on the part of older people, and Charles Taylor (1955) has also demonstrated that older people are more emphatic in their agreement or disagreement with attitude statements Vernon Jones (1929) reported that older teachers tended to view various types of conduct as clearly right or wrong and less often excusable than did younger teachers And Anderson and Dvorak (1928) found a similar emphasis by older individuals upon absolute right and wrong standards of conduct compared to views held by younger adults

ent (Pressey and Kuhlen, 1957)

And, third, adults seem to become more rigid with the passing of years Most of the objective evidence supporting this state-

ment, beyond that dealing with conservatism and dogmatism described above (which, of course, relate to rigidity), is to be found in studies of learning such as Ruch's (1934) or in studies of intellectual functioning conducted by standard intelligence tests However, clinical evidence which of course is more subjective and impressionistic, is in ample supply Very low positive correlations between age and the California F Scale have been reported (Adorno *et al*, 1950) And one fairly comprehensive study of age trends in "person ality rigidity' has recently been reported by Schaie (1958) subsequent to a careful study of the nature of behavioral rigidity icant until the 41–45 age group was reached Correlations between the rigidity measures and a measure of mental abilities (Thurstone's *Primary Abilities Tests*) were significantly positive at all ages, with a tendency for the correlations to be higher in the middle years and lower in the advanced years

Various features of the findings led this investigator to suggest the hypothesis that "optimal functioning at young maturity and during the middle years may involve the interaction of both flexibility and intellectual level while at the older ages maintenance of flexibility increases in importance" Certainly, the total array of data

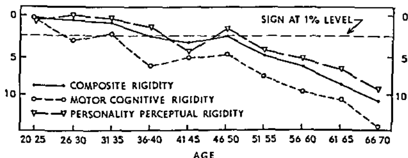


FIG 6—Mean decrements in flexibility on several rigidity measures (in T score points from the mean of the most flexible group) (From Schaie 1958)

(Schaie, 1955) From the latter factor analysis study it was concluded that behavioral rigidity might best be described along three dimensions motor cognitive speed, personality perceptual rigidity, and motor cognitive rigidity Appropriate tests of these three types of rigidity were administered to 25 men and 25 women in each semi decade of life from 20 to 70, with the results charted in Figure 6 The curves there presented are in terms of T score discrepancies from the most flexible group It will be noted that the least decline (though still highly significant) was found on the personality perceptual dimension, while the sharpest decline was found on the motor cognitive rigidity dimension It is of interest that decline on the personality perceptual dimension of rigidity was not signif on conservatism, dogmatism, bias, and rigidity suggests that older people likely will be handicapped in their adaptations to new situations and that this handicap typically becomes greater as age increases To an important degree, such personality traits may prevent the utilization of the full intellectual *capacity* of the individual to adapt

OTHER PERSONALITY CHANGES WITH AGE

There remains for comment a number of miscellaneous age changes in behavior tendencies

First, there seems to be an increasing tendency with age for people to *avoid* certain types of situations, a trend noted frequently enough to suggest that avoidance

behavior becomes increasingly an important means of adjustment The reduced willingness of older individuals to participate in research is a case in point When studying age trends in attitudes over the adult life span, Kuhlen (1955) observed that the most consistent trend among the various comparisons made was that of a greater omission of responses on the part of those older More recently Korchin and Basowitz (1957) and Basowitz and Korchin (1957) have noted in studies of verbal learning and of the perception of closure a marked tendency on the part of older individuals to omit responses even under instructions to guess if they did not know This increasing tendency to inhibit responses may reflect an increase in caution with age It is relevant that Guilford and Martin (1944) have noted an increased tendency for adults up to 50 years of age to become less carefree and more restrained and W R Miles (1935) has reported a correlation of $-\ 20 \pm\ 04$ between age and score on the dominance scale of the Bernreuter (However Miles [1933] reported no relationships between age and Bernreuter scores) These varied trends (avoidance tendencies inhibition of responses loss in carefreeness and increased submissiveness) which appear to have much in common psychologically will again be the subject of comment a few pages hence

A number of investigations of personality and adjustment in old age have been conducted by means of the Rorschach test While deserving attention in a review such as this such studies have in the present writer s opinion been relatively uninformative because of the lack of adequate norms of young adult performance lack of evidence of the meaning of the test responses in old age and the finding of only slight or no age differences when age contrasts have been made among individuals all of whom are of relatively advanced years

The lack of adequate young adult norms suitable for a reference point is evidenced in the fact that the typical old age group gives total responses averaging about 14–20 to the ten cards, a number usually compared to the mean of 30–40 responses reported by Beck (1944) and by Klopfer *et al* (1954) Such comparisons suggest a marked loss in productivity in old age with all that may be implied by such restriction of performance There likely is a decline with age in productivity, though it is doubtful if it is as great as the foregoing figures suggest Gurvitz (1953), one of the few investigators who sampled in one study a broad range of adult ages, reported responses (R s) of 30 1 for a 20–24 year age group, 26 9 for a 35 39 group and 22 1 for a 50–54 group of subjects (50 per group) of average intelligence Ames *et al* (1954) reported values of 19 5 for the seventies 15 3 for the eighties, and 15 0 for the nineties But generally, studies have been restricted to old age groups and to comparisons made with general norms for young adults A variety of studies of av erage" young adults (enlisted army personnel policemen, nurses) have yielded R s within the range usually reported for older people, thus raising serious question as to what the *appropriate* young adult norms are Those using the Rorschach with older groups should also it would seem accept the responsibility of providing data for a younger reference group with test administration by the same examiner(s) and with attention to the comparability of the groups contrasted The Rorschach protocols in the middle and older years vary with intelligence (Gurvitz, 1953, Caldwell 1954) and with socioeconomic status (Ames *et al*, 1954)

Various investigators (Klopfer 1946 Prados and Fried, 1947, Davidson and Kruglov 1952 Hays, 1952, Ames *et al* 1954, Caldwell 1954, Light and Amick 1956) either have reported similar formal findings for old age populations or have made similar interpretations of findings People in the older years are seen as having reduced drive, evidencing greater constriction and stereotyped thought processes, showing reduced judgment, emotion

al control social sensitivity and spontaneity Gurvitz (1953) basing his conclusions on a sample of 450 records (the largest number yet reported) distributed in blocks of 50 among three intelligence levels at each of three age groups concluded that the intellectually superior individual is able to maintain his personality integration relatively intact to at least the 50–54 age level (the oldest group studied) whereas by this age the typical person of inferior ability will show marked losses and evidence emotional d fficulties in dealing with the environment.

Caldwell (1954) has been appropriately critical of the practice of applying the conventional interpretations to Rorschach responses of people in the older years She noted that when a priori predictions were made regarding the relationship of Rorschach variables to age utilizing usual Rorschach rationale only 2 out of some 24 correlations were significant at the 05 level and both of these were in the direction opposite from that predicted on the basis of test rationale! The subjects in this instance numbered 47 averaged in intelligence just below the normal range and ranged in age from 61 to 92 The results suggest the need f

validity studies if the Rorschach is to be applied to older populations

Most studies which have compared groups of different ages within the *older* brackets have utilized unusually small numbers but in these studies as well as in studies where samples were of reasonable size (Kuhlen and Keil 1952 Ames *et al* 1954) little in the way of age differences has appeared This finding led the latter investigators to conclude that although age is a reasonably satisfactory variable along which to order developmental data during the growth period this is not the case in the same patterned periods chronological age is no longer a reliable predictor of the stage of the individual s development (Ames *et al* 1954 p 119) As a consequence of this conclusion these investigators classified their 200 records into normal pre senile and senile groups and proceeded to make comparisons among these groups Unfortunately the circularity of the procedure (i e groups were set up on the basis of Rorschach signs and then compared as to Rorschach signs) raises serious question as to the meaningfulness of the findings even though significant differences among these groups were reported

V Factors Related to Adjustment in Old Age

The basic purpose thus far in this chapter has been the description of age trends in adjustment over the course of the adult life span The next few pages will be devoted to adjustment in the later years and will concern not age trends but factors related to adjustment Available studies pertinent to this issue are difficult to evaluate Here especially does the problem of value judgments become serious With relatively little supporting evidence a *particular pattern* of behavior is often assumed to characterize the well adjusted older individual that is it seems to be assumed that there is *one* pattern of good adjustment in old age The pattern usually described includes active participation in a broad range of activities a variety of active social contacts with offspring and friends and a generally positive outlook on life In general students of adjustment in old age appear to neglect the possibility that a *number* of patterns of good adjustment may exist—that indeed for the person who is so inclined and *wants* it a life of quiet non participating sol tude may be the *good* life

Instruments utilized in the evaluation of adjustment in old age lack validation against basic types of external criteria wh ch in this writer s opinion should go far beyond ratings by interviewers and oth

ers who are likely to hold the same con cepts of what constitutes good adjustment as are built into the tests Very much needed as criteria for the validation of measures of adjustment are laboratory and clinical studies designed to assess the presence or absence of symptoms of adjustment, irrespective of specific stimulating condi tions, under relatively static and relatively stressful circumstances, as well as long-term studies in naturalistic settings in which the reactions of previously tested individuals to various aging crises can be assessed Since external criteria are not used, original misconceptions of what constitutes good adjustment not only are likely to go uncorrected but are likely, indeed, to be reinforced because of an unfortunate circularity that afflicts many available studies One example of such circularity was pointed out earlier in the instance of a Rorschach study In the various structured interview and paper-and pencil questionnaire studies one should, perhaps, not be surprised to find that "happy" and "unhappy" oldsters differ in hobby participation (see Table 10), especially since having hobbies en tered into their classification as happy or unhappy, or that those who "visit frequent ly" are better adjusted (Landis, 1942) when *"desire for visiting"* helped determine the basic adjustment score

TABLE 10*

CHARACTERISTICS WHICH DISTINGUISH THE HAPPIEST (UPPER THIRD OF DISTRIBUTION ON ADJUSTMENT SCORE—142 OR LESS CASES) FROM THE UNHAPPIEST (LOWER THIRD—122 OR LESS CASES)

Characteristic Which Is True of Percentages of Subjects Given in Succeeding Columns	Percentage		Difference
	Of the Happiest	Of the Unhappiest	
Live with child because they want to (based on 41 cases —22 happiest 19 unhappiest)	72 7	31 5	+41 2
Have plenty to do every day"	84 5	47 5	+37 0
Are able to do some kind of work now (based on 233	62 3	28 8	+33 5
	79 3	46 9	+32 4
	63 4	36 9	+26 5
Did you like to work?" Answer 'Yes, very much," rather than 'Considerably," 'Some" Not much," Not at all'	79 3	54 4	+24 9
Excellent or good general health rather than fair, poor	59 8	36 8	+23 0
	51 0	83 9	−22 9
	61 3	38 8	+22 5
	67 6	45 9	+21 7
	62 7	41 8	+20 9
	4 9	24 6	−19 7
	56 3	38 0	+18 3
	35 2	18 0	+17 2
	64 8	47 8	+17 0
	40 1	24 6	+15 5
	33 8	18 9	+14 9
	24 7	38 5	−13 8
	62 7	49 6	+13 1
	83 7	72 3	+11 4

* Source After Morgan, 1937

Data from three major studies of adjustment in old age are contained in Tables 10, 11 and 12 The first (Table 10) is from the classic study by Morgan (1937) of the adjustment of recipients of old age assistance in New York (city and upstate) The happy were distinguished from the unhappy in this study through the answers to five questions (1) Do these things (activities which the subject reported as occupying his daily time) interest you? (2) Do you have any hobbies? (3) Generally speaking do you enjoy life now? (4) What do you think is the greatest comfort to you in your old age? (5) What has worried you

and had many social contacts A similar study by Landis (1942) has yielded essentially similar results

A substantial number of studies of adjustment in old age have involved the use of an instrument entitled Your Activities and Attitudes' prepared by Burgess Cavan and Havighurst (Cavan *et al* 1949) Although the problem of circularity has not been avoided in this instrument and in the studies utilizing it it is to the credit of the authors that much statistical data on the reliability of the device the intercorrelation of its parts and the relationship of scores to ratings made by interviewers and associates of respondents have been presented (Cavan *et al* 1949 Havighurst 1951) Certain of the intercorrelations are presented in Table 11 The top portion of the table shows the relationship between various items in the schedule of adult activities and the total attitude score the latter being the measure of personal adjustment The sample on which this table is based is substantial for males each *r* is based on from 882 to 1048 cases for females from 1505 to 1818 cases For both sexes participation in groups and activities and frequency of attendance at religious services yielded highest correlations with adjustment, whereas frequency of seeing friends and closeness of relationship to children and close relatives had lowest relationship to adjustment

The bottom portion of the table contains the correlations between various parts of the attitude inventory and the total score It will be noted that those subparts relating to happiness leisure work and feeling of usefulness were most highly cor

TABLE 11*

RELATION TO TOTAL ADJUSTMENT ATTITUDE SCORE OF (1) VARIOUS ACTIVITY ITEMS (*Top Half*) AND (2) PART SCORES ON THE ATTITUDE SCALE (*Lower Half*)

Total Attitudes Score versus	Males	Females
Number of close friends	27	23
Frequency of seeing friends	18	20
Frequency of seeing young friends	18	14
Number of leisure time activities	21	26
Frequency of attendance at religious services	41	36
Number of organizations in which person is active	29	26
Four questions on social morale	22	23
Closeness of relationship to children and close relatives†	15	07
Companionship or personal contacts†	27	15
Participation in groups and activities†	43	39
Health	48	54
Family	40	37
Friends	56	55
Leisure	73	70
Organizations	54	52
Work	59	61
Economic security	38	41
Religion	35	29
Feeling useful	62	60
Happiness	65	64

* Source After Cavan *et al* (1949) pp 134 and 196
† Based on a composite of items

related with the total score It is interesting that the religion subtest correlated lowest of all with the total score although the *activity* of religious participation (mentioned above) was relatively highly correlated with adjustment If one compares the relative rank of these correlations in their respective portions of the table rather than their absolute magnitude it may, perhaps be inferred that the meaning religion, as such has for the individual is not so important to adjustment as are such variables

as the social interaction and sense of be longing that may characterize participation in religious activities It is of interest in this connection that Moberg (1953) has reported that holding orthodox religious views is related to adjustment in old age as measured by the Burgess Cavan Havig hurst scale as also is participation in reli gious activities

The development of this scale for the measurement of adjustment in old age at the University of Chicago gave rise to a number of theses and dissertations upon which published research reports have been based Studies by Ju Shu Pan (1948) Shanas (1950) Britton and Britton (1951) Schmidt (1950) and Britton (1953) are illustrative of the product of this extensive research program adding many details to and corroborations of the facts presented in Table 11

The most recent comprehensive investi gation of adjustment in old age (Kutner *et al* 1956) adds a highly significant point to the findings thus far cited certain variables may be positively associated with adjustment in one socioeconomic group and negatively associated in another In this investigation a score referred to as a mo rale score was based on answers to seven questions such as How often do you feel there s just no point in living? All in all how much unhappiness would you say you find in life today? How much do you plan ahead the things you will be doing next week or the week after—would you say you make many plans a few plans or almost none? The question then concerned the degree to which various activities and circumstances bore a relation to morale or adjustment.

Table 12 contains selected findings showing the relationship of a number of variables to morale in the instance of those of high and low socioeconomic status The reader s attention is invited (*a*) to the in stances where the direction of relationship is reversed in the two economic levels and (*b*) to the instances where high socioeco- nomic status (and all that such status may mean in terms of self regarding attitudes security resources of habits skills and ap preciations which may be drawn upon for the gratification of needs) seems to out weigh the effect of what would seem almost obviously a negative influence A case in point is poor health ' Surprisingly among the high economic status group morale of even those in poor health is in the high di rection though to be sure a higher pro- portion of those with good health fall in the high morale group The situation is re versed in the low socioeconomic group Those in good health are found in the high morale group only a little more frequently than in the medium and low morale groups whereas those in poor health are found much more frequently in the low morale

[illegible]
ing is better than friends and acquaint ances) or a negative self image bears al most the same relationship to morale in the two economic groups as was true of good or poor health

Findings relating to social interactions in general (i e relatively isolated or not iso lated) or with children and friends are es pecially noteworthy in view of the great importance attributed to such variables in other studies It should be noted though that in contrast to most other studies the basis of this particular morale score in volves *no* questions relating to social inter action As is evident in the table those in high socioeconomic groups who have less in the way of social contacts (relatively isolated visit children less often than once a week or have no children) are to be found in the high morale group just as fre quently (in fact, slightly more so) as those who have more of these types of contacts and those who had no friends or who vis ited friends less than once a week had just as high morale as those who visited friends once a week or more As will be observed in the table quite different trends charac terized the low economic group It may

well be that the lack of dependence of higher economic groups upon social interaction is due to their possessing greater "internal" resources (interests, appreciations) to draw upon as a means of satisfying needs

Most studies (e g, Morgan, 1937, Landis, 1942, Cavan *et al*, 1949, Kleemeier, 1951) emphasize the importance of work as a factor in good adjustment in old age The facts relative to this matter in Table 12 are of especial interest because those working and those retired are matched in terms of weekly income It will be noted that, income level for income level, those working are more frequently found in the high morale category than are those retired But greater income does not

TABLE 12*

RELATION TO MORALE IN OLD AGE OF VARIOUS ACTIVITIES AND CIRCUMSTANCES BY PERCENTAGE DISTRIBUTION OF INDIVIDUALS OF HIGH AND LOW SOCIOECONOMIC STATUS

	No of Cases	Morale Status (Per Cent)		
		High	Medium	Low
Health				
High status, good health	137	50	28	22
High status, poor health	66	44	30	26
Low status, good health	147	39	31	30
Low status, poor health	150	20	30	50
Self image				
High status, positive self image	112	53	32	15
High status negative self image	91	43	25	32
Low status positive self image	113	40	37	23
Low status, negative self image	184	23	27	50
Social isolation				
High status, isolated	85	51	28	21
High status not isolated	117	47	30	23
Low status, isolated	194	25	28	47
Low status, not isolated	103	37	36	27
Visiting with children (+ or − once a week)				
High status, often	101	47	29	24
High status less often	29	65	21	14
High status, no children	72	43	35	22
Low status, often	109	28	30	42
Low status, less often	45	36	28	36
Low status, no children	143	27	31	42
	88	49	29	22
	77	48	27	25
	36	47	33	20
	102	35	37	28
	100	29	33	38
	87	23	20	57
	29	31	31	38
	44	49	30	21
	80	65	25	10
	100	23	33	44
	35	37	29	34
	17	35	35	30

* Source After Kutner *et al*, 1956

add greatly to the morale of the retired, whereas *among the working* there is a sharp rise in morale with higher income Presumably, higher *earned* income reflects a more significant role as well as differences in style of living, etc

A number of miscellaneous findings regarding factors related to adjustment in old age should be mentioned In general, married individuals are better adjusted than those widowed divorced or single but Kutner's findings (1956) suggest that this may vary for socioeconomic levels There seems to be some evidence that men have a more difficult time adjusting to aging (retirement) than do women (Landis 1942, Kutner 1956), but evidence is not consistent as to which sex is generally happier and better adjusted in old age No reference has been made here to the relationship of role changes and age identification to adjustment As was pointed out earlier, shifts into roles which offer fewer opportunities for need satisfaction and which in themselves imply status losses are related to lower adjustment To a degree, self-identification with a younger age tends to insulate the individual against the impact of such role shifts

Earlier in the chapter the dimension of time perspectives was stressed as a significant variable in developmental psychology It would appear from a number of studies and reports of counseling experiences that the inability of old people to maintain a forward looking or future orientation is a major factor in poor adjustment Conkey (1933) emphasized, as a result of a study of 100 old people, that living in the past (reminiscing) was a hindrance to good adjustment Frequency of planning ahead was included in Kutner's morale scale, and De Gruchy (1946) reporting on cases from the Old Age Counseling Center in San Francisco, emphasized that rehabilitation of older people depended largely on their developing a purpose in life and achieving a forward orientation through pursuit of those purposes Pressey (1957) has similarly emphasized, though in a different way, the potentialities of the *future* in old age through his exploratory field studies of the potentialities of old age

Despite the inadequacies of the studies summarized in this section—inadequacies of the type described in the opening paragraph—the data on factors related to adjustment are becoming sufficiently extensive so as to provide a source of hypotheses not only for those interested in programs designed to promote adjustment but also for those interested in further refinement of designs for future research along similar lines Particularly challenging to future investigators should be the findings of Kutner which serve not only to question certain of the platitudes regarding good adjustment in old age but to emphasize that what holds for one subculture may very well fail to be true in another

VI Relation of Data on Adjustment to a Dynamic Theory of Aging

It seems appropriate to conclude this chapter on adjustment with a brief comment relating the data here presented to what may be called a dynamic theory of aging Instead of viewing adjustment as the dependent variable to be studied with reference to chronological age as the independent variable, as has been done thus far in this chapter, adjustment may well be viewed as one of the significant age related *independent* variables which may partially explain a wide variety of personality and performance changes that occur with increased adult age It is probable, of course, that a variety of interacting causal conditions are responsible for age changes in psychological characteristics (1) organic deficits, both neural and general, (2) strength and variety of pre existing habit patterns, (3) cultural opportunities or lack thereof for need gratification, and (4) the changing dynamic and motivational patterns The latter warrants particular emphasis because it appears that motivational variables (especially anxiety generated de-

fensive behaviors) are unduly neglected, and particularly so in those laboratories where the more precise types of aging studies are being conducted

A dynamic interpretation of aging is not new Reigel has summarized a number of viewpoints in chapter xxiii of the present volume Among the writers whose formulations seem most relevant are Atkin (1940), Kaufman (1940), Tolman (1948), Frenkel Brunswik (1949), and Schuster (1952) In general, these writers have offered tentative explanations of rigidity (which may well be one of the central personality traits reflected in a variety of aging trends) or have tended to view many aging patterns as essentially defensive mechanisms or maneuvers generated by the anxiety arising from the threats posed by the physical and social losses accompanying increasing age Applezweig (1954) has suggested that increasing insecurity may be the factor underlying increasing rigidity with age, and Basowitz and Korchin (1957) and Korchin and Basowitz (1957) have given a dynamic interpretation to certain age differences in learning and perception Kuhlen (1955) has interpreted avoidance behavior (response omissions on an attitude scale) and the taking of extreme positions on attitude scale items (Taylor, 1955) as motivated by insecurity

A variety of data presented in this chapter serves to suggest that older people are [illegible] conservative, and more rigid and to evidence more avoidance behavior Other studies, not summarized in the present chapter, demonstrate that older people perform less well on digit recall and digit symbol substitution tasks as well as on general intelligence tests and are much more handicapped on complex performance tasks than on simple ones It is relevant that other writers and investigators, not concerned with the matter of aging have shown that, independently of age, individuals who are insecure, anxious or under stress differ from those who are secure, non anxious, and not under stress in many of the same ways that older adults differ from younger adults Thus it has been shown that anxious students (1) take more extreme positions (Lewis and Taylor, 1955) (Brim [1955] has interpreted extreme positions on attitude items as stemming from insecurity) (2) perform less well on digit symbol substitution tasks (Mandler and Sarason 1952), on digit recall tasks (Moldawsky and Moldawsky, 1952) and on intelligence tests (Hutt 1947) and (3) are handicapped on complex tasks to a greater degree than on simple tasks (Pickrel 1958) The resemblance of differences between anxious and non anxious subjects comparable with respect to age to differences between older and younger adults seems too remarkable to be dismissed as coincidence

In total it would appear that a strong case can be made for a dynamic interpretation of aging Conservatism, for example may be viewed essentially as a clinging to accustomed means of gratification and an avoidance of the threats inherent in new situations The dogmatic taking of extreme responses on attitude scales may be viewed as an overstructuring of the situation to avoid the threat of ambiguity Dislike of change which, according to Strong (1943) is highest in youth and the older years may be generated by insecurities common to both adolescence and the later years Difficult performance tasks not only are likely to generate more anxiety than simple tasks but by their very nature present to the subject problems involving alternative competing tendencies Since it is under these circumstances that anxiety becomes handicapping and since older individuals seem more susceptible to stress, the relevance of the material of this chapter to an explanation of reduced performance in old age on difficult tasks seems apparent It should be relatively simple to introduce appropriate measures into aging studies or to manipulate the experimental situation so as to engender stress and thus to test hy

potheses of the type suggested by the fore going considerations in a context that would also permit some assessment of the contribution to aging effects of the other types of variables mentioned in the intro duction to this section

VII Summary

1 Although the study of life adjustment in aging has been and continues to be handicapped by problems of definition and measurement data are beginning to accu mulate in sufficient variety and volume not only to permit the identification of major age trends but also to stimulate much needed theorizing about psychological ag ing along dynamic lines

2 A variety of data on age changes in 'avenues' of need gratification (goals in terests), adjustive predispositions (con servatism dogmatism avoidance) and per formance in various tasks can be related if two broad contrasting motivational tend encies are postulated Related to the basic pattern of expansion and restriction that characterizes the life cycle are suggested first, a need for continued expansion (achievement sense of significance and on goingness self actualization) which is most directly evident in the expansive years and evident indirectly and vicariously in the restrictive years and second an in creasing need to erect ego defenses against the anxiety generated by the physical and social losses that become increasingly evi dent from the latter part of young adult hood onward

3 The major symptoms of adjustment include (*a*) feelings of happiness and con tentment, and positive self regarding at titudes, (*b*) freedom from handicapping anxiety, and (*c*) evidences of frustration tolerance and ability to deal effectively with stressful, threatening situations The rela tionship of such symptoms to adult years will presumably be determined by the de gree to which the total personal and en vironmental circumstances associated with a given age offer potentiality for gratifica tion of varied needs and/or poses threats or frustrations In general, it might be an ticipated (*a*) that over all measures of ad justment, such as happiness ratings, will show a curvilinear relationship to age, corresponding roughly to the pattern of expansion and restriction, (*b*) that level of anxiety under "normal' conditions will be essentially unrelated to age but that for some groups various circumstances may tend to focus adjustment problems at par ticular ages (e g , age 30 for single women, the forties for career frustrated men) and that, in any event, specific adjustment problems (e g , developmental tasks) may contribute to anxiety at particular ages, and (*c*) that, because of social and physical losses that accompany aging as well as the seriousness of the consequences of life-dis-ruptions once commitments are made (e g , to family and career), it may be hypothe sized that with increasing adult age will come increasing susceptibility to threats posed by life crises and other stresses In general, though with important excep-tions, the data summarized in this chapter are compatible with such general hy potheses

4 However, it is apparent that chrono-logical age is at best only a convenient means of ordering developmental data and is important to adjustment mainly through the influence of age related variables that have greater psychological significance Thus it would be hypothesized that the degree to which various phases of life (i e , various age periods) offer basic gratifica tions or pose serious threats and thus in fluence adjustment will depend upon such matters as the *meaning* of life and aging to the individual, the *role* he occupies at a given age rather than his age as such, his general *"style of life"* and personality makeup (e g , rigidity flexibility), *situa tional factors* that may pose environmental stresses, and *personal factors* (e g , capaci ties) which not only may be threatening in their own right but also may reduce the individual's ability to cope successfully with his environment and to achieve gratifi

cations in usual ways and to usual degrees Studies are beginning to appear which take account of these more individual and personal variables, and emerging evidence already testifies to the fruitfulness of studying aging in the framework of more general theory and with a better conceptualization of what increased chronological age implies

5 Longitudinal data bearing on personality change and adjustment are beginning to appear, though relating mainly to young adulthood and early middle age Such evidence tends to demonstrate the possibility as well as the probability of continued personality growth well into adult years and does not exclude the possibility of significant change occurring even in advanced years There is however a basic continuity or persistence of personality and adjustment characteristics over long periods of the adult years but interdisciplinary longitudinal research is already indicating that the study of age trends in personality and adjustment must take into account variables such as those referred to in the preceding paragraph

6 Studies of factors related to adjustment in old age leave much to be desired but they tend to emphasize the importance of positive self images and age identifications being busy and occupying significant roles (e g employed married) having varied social contacts and activities and being oriented toward the future Health is an important factor as is also socioeconomic status However recent research has demonstrated that factors usually found to be related to good adjustment—indeed conceptualized as a part of good adjustment—may evidence opposite relationships to adjustment at different socioeconomic levels

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